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INTEGRATED TACTICAL COMMUNICATIONS SYSTEM

(INTACS).

AD B002031

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Task III. Communications System Effectiveness and Cost Methodology Development.

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Hq. Army Signal School
attn: ATSN-CTD-CS-S
Ft. Gordon, Ga. 30905

MARTIN MARIETTA

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INTACS

SOLDIER COMMUNICATORS
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ABSTRACT

The cost and effectiveness methodology developed in Task III of the INTACS program offers a direct, dependable, and flexible means for evaluating the capabilities and cost of the candidate mid range time frame Army communications systems concerned. At the same time, it constitutes an effective tool for ranking these systems further on the basis of technological risk. Thus, the methodology developed will facilitate the selection of a preferred system as intended.

FOREWORD

This report has been prepared by the Martin Marietta Corporation for the Commandant, USASESS, in accordance with the provisions of Contract No. DAAG39-73-C-0248. It documents the results of the contractor's activity in response to the requirements contained in Task III and is intended as an input to the on-going work of the INTACS program. The comments, conclusions, and recommendations contained herein represent the professional views of the contractor and not necessarily those of the Department of the Army.

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1.0 INTRODUCTION

This report documents the work performed during Task III, Cost and Effectiveness Methodology Development, and summarizes the results of that effort.

1.1 TASK III OBJECTIVE

The objective of Task III was to develop the approaches and procedures to be employed in the evaluation and rank-ordering of the communications system alternatives to be developed in Task V. Specific Task III efforts undertaken to satisfy this objective were as follows:

- Development of a tactical communications system effectiveness analysis methodology;
- Development of a cost analysis methodology;
- Development of a risk analysis methodology;
- Development of a sensitivity analysis methodology;
- Development of a cost/effectiveness tradeoff analysis methodology.

While the objective of Task III was to develop methodologies, it is necessary, in order to fully understand, appreciate, and evaluate the methodologies, to present their basic elements within the context of their application. Therefore, this report presents brief discussions of the effectiveness, cost, risk, and cost/effectiveness methodologies within the framework of their application in Task V, Development and Analysis of Mid Range Time Frame (MRTF) Communications Systems. Particular emphasis is placed on the role these methodologies will play in assisting system designers in the development and refinement of alternatives and in providing decision-makers with an assessment of the implications associated with pursuing various system options. Detailed descriptions of the methodologies developed in this task are presented in appendices to this report.

Each methodology is defined in terms of four basic elements: 1) the output to be produced; 2) the input to be operated on; 3) the analytical

procedures, criteria, techniques, and models to be utilized; and 4) the sequence of procedures to be followed in their application.

The procedure for development and analysis of the MRTF communications systems and the application of the methodologies within this procedure is detailed in Section 2.0. The effectiveness evaluation criteria (on which system effectiveness evaluation, design refinement, and tradeoff analysis will be based) are set forth in Appendix A. The cost methodology and referenced cost methodology literature are presented in Appendices B and C. The three major computer models that will be used in Task V are briefly described in Appendix D. A sample communications system evaluation, using the procedures developed in Task III, is presented in Appendix E, and the sensitivity analysis of the procedure is presented in Appendix F. Appendix G highlights the methodology for the evaluation of single channel systems. The report concludes with a table of abbreviations (Appendix H) and a glossary of terms (Appendix I).

1.2 BACKGROUND

The overall Integrated Tactical Communications System (INTACS) study program is intended to develop detailed and comprehensive communications support and implementation plans for all aspects of Army tactical communications support. These plans must describe the systems, materiel, doctrine, and organizations required for such support during two explicit periods:

- The mid range time frame (MRTF), from 1976 through 1986;
- The long range time frame (LRTF), from 1987 onward.

The implementation plans must include a time-phased sequence of events, milestones, and decision points as needed with regard to the time periods concerned.

The INTACS program is divided into 17 tasks, with the first seven intended to address the MRTF and the remainder to consider the LRTF. In each of these two sets of tasks, the following basic activities are prescribed:

- Refinement of alternative MRTF/LRTF communications systems;
- Configuration of alternative MRTF/LRTF communications systems;
- Establishment of an ordered, weighted set of criteria for evaluating, comparing, and ordering;
- Establishment of a cost and effectiveness methodology for evaluating, costing, comparing, and ordering of alternative MRTF/LRTF communications systems;

- Determination of the size and initial cost of the baseline and alternative MRTF/LRTF communications systems;

- Development of communications support requirements for alternative concepts;

- Analysis and evaluation of candidate MRTF/LRTF communications systems, and identification of design deficiencies and unsuitabilities of alternatives to permit subsequent redesign where permissible;

- Determination of the comparative cost of alternative systems;

- Tradeoff analysis, comparison, and rank-ordering of candidate systems.

A graphic depiction of the logic and flow of the foregoing activities is presented in Figure 2.0-1 (found on page 8).

1.3 APPROACH

If the INTACS program is to successfully achieve the upgrading of the future communications posture of the Army, it must attain a desired level of credibility early in the effort. The task of building this foundation of credibility commences with the development of sound methodologies.

The remainder of this section summarizes the fundamental approach by the study team in establishing sound methodologies in the areas of effectiveness, cost, risk, sensitivity, and system cost/effectiveness tradeoff.

1.3.1 Effectiveness Analysis Methodology

System effectiveness refers to the overall capability of a system to accomplish its intended mission. The mission of an Army tactical communications system is to provide deployed units with the communications support needed to accomplish their objectives. Thus, the ultimate measure of the effectiveness of any tactical communications system is the degree to which that system enhances the probability of mission accomplishment by the tactical units supported.

Of course, the calculation of this probability in a totally credible manner is an impossible task. Primary deterrents are the difficulties associated with identifying the factors upon which mission accomplishment depends, the manner in which these factors are related, and the absence of operational data upon which the analyst can draw to determine the way communications affects these factors.

In approaching Task III, therefore, the study team decided to base the evaluation of INTACS alternatives not on the success likely to be enjoyed by the units supported, but upon the degree to which each alternative possessed the characteristics deemed inherently desirable in a tactical communications system. The Department of the Army's INTACS Study Advisory Group (SAG) and the Contracting Officer's Representative (COR) concurred.

1.3.2 Cost Analysis Methodology

Two types of cost information are required to meet the needs of the INTACS program:

- Total life-cycle cost (LCC) estimates for each alternative to be designed and analyzed in Task V;
- A summary, by year, of costs required to implement each alternative (necessary to develop support and implementation plans for the preferred concept in Tasks VI and VII).

The cost methodology must produce the required cost information to support the subsequent analysis. One cost approach will estimate the total LCC of alternatives to aid in selecting a preferred concept, while the other will aid in programming, budgeting, and controlling the preferred alternative support system concept. The cost methodology will be applicable in Tasks V, VI, and VII, as indicated in the paragraphs that follow.

Task V is to develop a candidate communications support system for each alternative concept and perform cost, effectiveness, and sensitivity analyses to recommend a preferred system. The LCC methodology will be used in estimating costs of the alternative system concepts to be used in trade-off analysis.

Task VI will produce a detailed communications support plan based on the Government's selection of a preferred system. In this plan, manpower and training costs for the specified organizations are required, along with adjusted procurement and inventory costs based on identified equipment needs and inventory shortfalls to aid in refining the materiel program. A subset of the described LCC methodology will be used to determine these costs.

In Task VII, yearly costs are required for programming, budgeting, and control purposes. The methodology of time-allocation of costs will be used to produce these cost estimates.

In developing this methodology, it was assumed that, for the period of interest (1976 to 1986), all equipment to be fielded is either on the shelf or currently in the research and development (R&D) process. As a result, either R&D costs are sunk, or estimates of such costs have already been developed and are available. A second constraint on the development of the methodology was the type and availability of existing cost data.

Elements of total LCC and time-allocation of cost categories for which estimates are to be developed were identified on the basis of a review of appropriate Department of Defense and Department of the Army regulations and other available data to determine those for which estimates could be developed. Existing models and data were reviewed to determine the extent to which they would be applicable to the needs of the INTACS program. On the basis of this review, the procedures were then identified and developed for calculating the required LCC and time-allocation of costs.

Three cost constraints will be applied in the mid range time frame evaluation and implementation:

- Total hardware cost constraint
- System life-cycle cost constraint
- Annual cost constraint.

1.3.3 Risk Analysis Methodology

The risk analysis methodology is a procedure for assessing the potential technological hazards associated with the MRTF alternative communications systems. A risk analysis is required because the implementation of an alternative might require the development of equipments not currently available. In carrying out such developments, the possibility exists that equipment with the required characteristics cannot be developed within the time period of interest. The risk analysis flags this potential difficulty so that it will not be overlooked in choosing a preferred alternative.

1.3.4 Sensitivity Analysis Methodology

Since most of the input parameters for Task V deal with the future and do not possess the desired degree of accuracy, a sensitivity analysis will be performed as a means of considering the uncertainty. A set of inputs may be little-known, so that estimates may be subject to error. In addition, the subjective utility allocation may contribute to a lack of precision. To include both sources of error, the sensitivity analysis is conducted in two parts:

- Parameter sensitivity analysis
- Utility allocation sensitivity analysis.

The parameter sensitivity analysis consists of changing an assumption or input parameter by a specified amount and determining the effect of the change on the figure of merit (FOM). The second part is to determine the effect of a slightly different utility allocation on the FOM for each system.

1.3.5 Cost/Effectiveness Tradeoff Analysis Methodology

The cost/effectiveness tradeoff analysis will be the last phase of the cost/effectiveness analysis effort prior to final selection of a preferred alternative. The first step will be to construct a summary table to aid in identifying significant differences among the alternatives. Next, those alternatives clearly dominated by others in cost, effectiveness, and risk will be identified; alternatives that exceed established cost thresholds will also be identified. After the identification of high-risk alternatives, an effectiveness/cost/risk sensitivity analysis will be performed. Finally, consideration will be given to attributes contained in the summary table.

2.0 METHODOLOGY FOR DEVELOPMENT AND ANALYSIS OF THE MRTF COMMUNICATIONS SYSTEMS

The Task V methodology (Task V Task Execution Plan) developed in Task III is described in this section. Figure 2.0-1 shows the principal elements of this methodology, the interrelationships between elements, and the chronological order in which these elements will be carried out. A brief overview of the methodology is presented in the remainder of this section. Each of the eight elements that comprise the methodology are explicitly treated in Sections 2.1 through 2.8, respectively.

As portrayed in the methodology flow diagram (Figure 2.0-1), the multistage procedure begins with the network sizing task (Step 1), in which the essential communications system characteristics that will best meet the COMSRs developed for the EAD force model are determined. The SIMCE model will be utilized as the primary tool for definition of the communications system requirement parameters. These requirements, the performance criteria developed in Task III, and the MRTF concepts refined in Task IV are the essential inputs to the MRTF candidate system development task (Step 2). Various implementation approaches will be conceived and organized into alternative MRTF communications systems. Existing and planned equipment, as specified in Appendix G of Task IV, will be considered in formulating these candidate systems. Concept ALPHA, based on the Government-provided EAD baseline concept, will also be formulated, using existing and planned equipment. Concept ALPHA will be derived to provide a reference system for system evolution and for comparison of the other candidate systems. When approved by the Government, the candidate systems will provide the major inputs to Steps 5, 6, and 7, in which the candidate systems are evaluated in terms of communications system effectiveness, cost, and risk and sensitivity.

In Step 3, the SIMCE and CASE/TD-18 communications system models will be utilized as design tools to evaluate and refine each candidate system. The models will be used for each concept, and the results will indicate the need for changes in system parameters and configuration. In Step 6, system analysts will evaluate other effectiveness aspects to determine possible system parameter or configuration improvements. In addition, the Government will conduct an EMC/EMV analysis that will be provided as input to the system evaluation task. The refined candidate systems, as defined by their configurations and associated effectiveness, cost, and risk evaluation, will then be analyzed as to the parameter variation in the sensitivity analysis task (Step 7). The results of the cost, effectiveness,

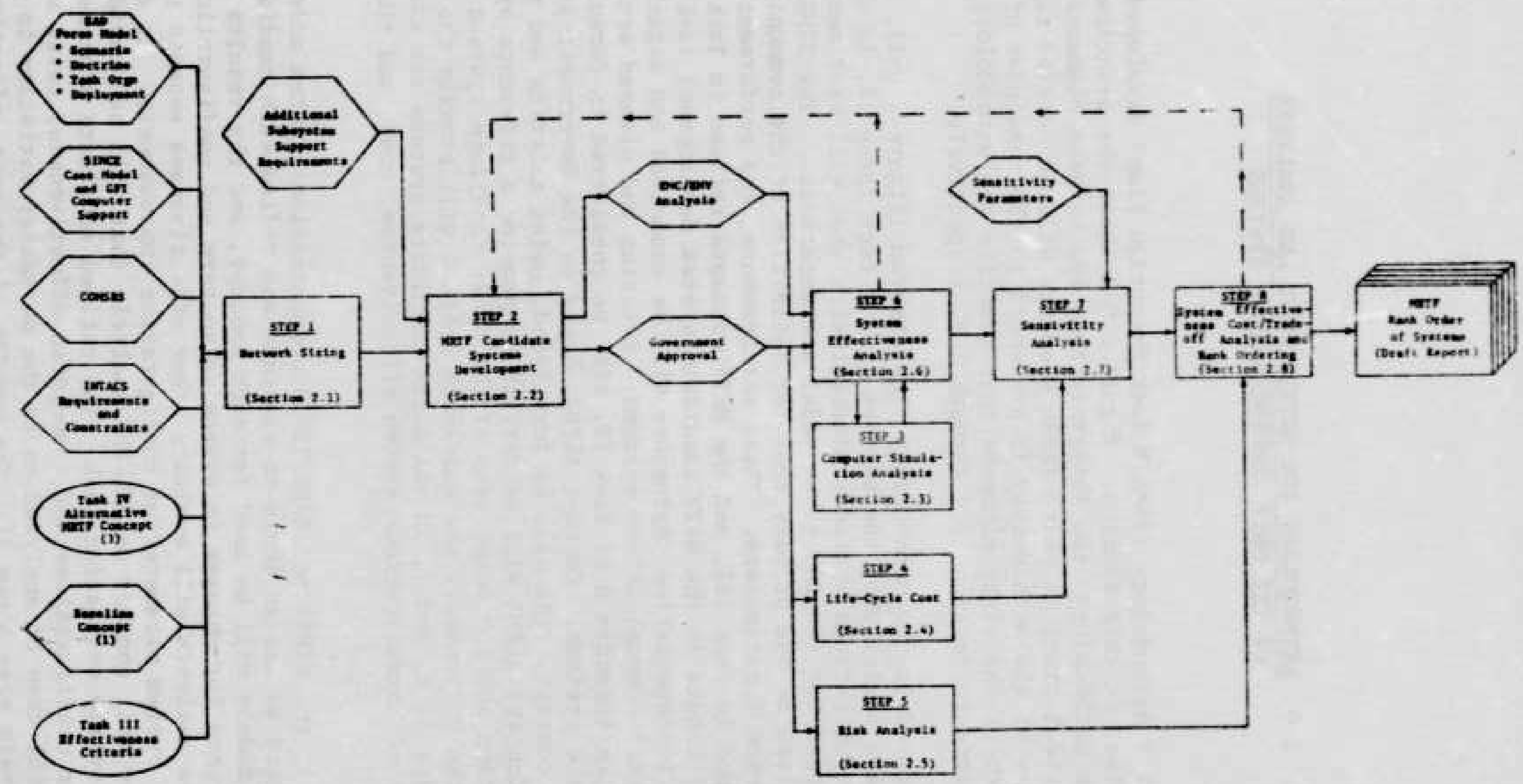

FIGURE 2.0-1 Procedure for Development and Analysis of MRTF Communications Systems

and risk and sensitivity analyses will be used by the system cost/effectiveness and rank-ordering task (Step 8), to refine the alternative systems and rank-order them with sufficient documented rationale to permit Government selection of the preferred system. The Government-preferred system will then be documented; the preferred system communications support plan in Task VI and the MRTF implementation plan in Task VII will be identified.

2.1 NETWORK SIZING

The purpose of the network sizing effort in Task V will be to determine the minimum channel allocations, throughout the system, that would successfully meet the communications support requirements (COMSRs). These channel requirements will be used as a base from which system designers will determine equipment deployments for the alternative communications systems.

Network sizing will be accomplished by using SIMCE to determine the relationship between channel requirements and design GOS. An analysis of this relationship will produce LINK GOS upper limit for system design. The results of sizing will be the capacity in channels of each link of the network and equipment allocations for each unit in the system.

The size of a communications system is specified by the locations of its nodes and links, the link capacities, and the equipment allocations. To determine these parameters, the Task V team will examine unit-to-unit needlines and channel requirements to determine the relationship between link capacity and GOS.

The Government-furnished information to be used for sizing includes:

- COMSR data and data description
- EAD force model
- EAD deployment
- SIMCE model.

The COMSRs were produced from the following sources:

- The Government-furnished force model with unit name, number, TOE, and location for over 4000 units;
- Data forms (completed by military communications experts) that recorded, for each typical unit, its communications requirements by mode.

This information was processed by a series of programs, including a force model program to place the appropriate data in the format required by SIMCE. The three files prepared for input to SIMCE contain specific unit data, typical unit names, and the user communication requirements.

With the elimination of the Field Army echelon, the CONAF COMSR data base originally supplied by the Government must be revised for the new EAD force structure. It is the purpose of Task XVII to develop an EAD COMSR data base that reflects the user requirements of the units in the EAD force structure. The EAD force model specifies each individual unit and the echelon to which the unit belongs. The EAD deployment provides the location of these individual units.

SIMCE will be used in network sizing to provide unit needline traffic volume, channel requirements, and GOS. (SIMCE is described in Appendix D.) The task of sizing will be performed separately for Theater Army, Corps, Division, and Separate Brigade. The sizing task can be broken down into five steps:

- Compute unit needline traffic
- Compute unit-to-unit channel requirements
- Determine link capacity-versus-GOS curve
- Determine equipment allocations
- Determine LINK GOS upper limit.

2.1.1 Compute Unit Needline Traffic

The first step in the sizing task will be to conduct a SIMCE-aided analysis to determine unit-to-unit traffic volume. The study team will identify the units to be sized and the location of nodes in the echelon. SIMCE will be run to determine the traffic between all specific units. This information will then be used to identify the busiest units, relocate nodes, and determine equipment allocation for the individual units.

2.1.2 Compute Unit-to-Unit Channel Requirements

The second step in the sizing task will be to determine the number of channels required by each pair of communicating units. This step will use the unit needline traffic volume determined in the first step. Unit-to-unit channel requirements will be computed, using the Erlang B formula. The analysis will provide an estimate of the upper limit on the number of channels required between a pair of units.

2.1.3 Determine Link Capacity-versus-GOS Curve

The purpose of this step will be to determine the sensitivity of link capacity to design GOS. SIMCE will be used to determine channel requirements for several values of design GOS.

The system designer will refine the locations of nodes and links in the network, using the unit-to-unit traffic from Step 1 as a guide. SIMCE

will then be run, connecting each unit to the nearest node and, if necessary, relocating nodes to improve design. The system designer will input a routing scheme and a design GOS to SIMCE, to determine channel requirements for all links in the network. The analysis will be repeated for various values of GOS, to produce a channel requirement-versus-GOS curve. This curve will help the designer determine the point at which a slight increase in GOS requires a large increase in link capacity.

2.1.4 Determine Equipment Allocations

The unit needline traffic volume and the unit-to-unit channel requirements from Steps 1 and 2 will aid in the determination of equipment for individual units. Equipment allocations for nodes will be determined by the designer after examination of the SIMCE-provided channel requirements for links, distances between nodes, and the volume of traffic over each link. The designer will also note the requirements of each individual unit for secure equipment, to ensure proper allocation of this equipment. Then the recommended equipment for each unit will be compared to the unit's present TOE equipment allocation.

2.1.5 Determine LINK GOS Upper Limit

The fifth step will use the output of the comparative analysis conducted in Step 4 and the channel capacity-versus-GOS curve developed in Step 3 to analyze and determine the LINK GOS upper limit to be used for system design. In Step 3, the link capacity required to meet a specified GOS was determined, and in Step 4, equipment allocations were established. The next step will be to combine the information from these two analyses and determine the maximum value of GOS to be used for system design. An analysis based on this consideration will be conducted, and a LINK GOS upper limit for system design will be determined. This value of GOS represents the highest value of GOS that the alternative systems can be expected to attain.

2.2 DEVELOPMENT OF MRTF CANDIDATE SYSTEMS

The objective of this task is to develop four candidate MRTF communications systems that will be analyzed and evaluated in Steps 3, 4, 5, 6, and 7 of Figure 2.0-1 and subsequently refined and rank-ordered in Step 8 of the diagram. The communications system design will identify the communications resources required to support the selected concepts and communications support requirements, by echelon, in terms of equipment, facilities, procedures, and system organization. The task will assign communications resources to establish the communications networks, communications nets, special communications subsystems, and organic communications capability, in accordance with established requirements. This task will consist of four subtasks:

1 Review Task IV hardware for completeness and make modifications where required; provide equipment characteristics for evaluation;

2 Identify organic communications support requirements;

3 Identify additional communications support requirements;

4 Develop MRTF candidate communications systems.

In Subtask 1, the procurement list of communications equipment from which the systems will be configured will be updated. Each item of equipment whose electromagnetic characteristics are required for input into the EMC/EMV analysis will be defined.

In Subtask 2, the organic communications support requirements for each unit will be identified and consolidated to permit the assignment of equipment and resources to be made in Subtask 4. Identification of organic requirements will be based on: 1) review of the COMSR data; 2) evaluation of the output from the network sizing tasks; and 3) review of other requirements documentation.

Subtask 2 will essentially follow the procedure outlined below:

- Identify organic communications requirements on a unit basis, in accordance with checklists and tables for the following:
    - Interunit traffic requirements
    - Intraunit traffic requirements
- Review stated requirements for:
    - Identification of duplications and omissions
    - Comparison with adopted standards
    - Verification of minimum essential requirements.

In order to ensure development of a cost/effective system that minimizes inconsistencies and overequipping, all available communications means must be considered simultaneously when unit organic requirements are being determined. The operational features, limitations, and capabilities of each of these means will be considered during resource assignment. The advantage offered by this approach is that it affords a view of the total communications requirements picture for each unit. This provides perspective and insight to the evaluation and resource assignment procedure that would not be possible if, for example, multichannel and organic requirements were evaluated separately. Tabulation of all requirements for each unit on a single record will facilitate this advantage.

The procedure referenced above permits assignment of equipment and resources as soon as requirements are determined, provided a resource inventory is available.

The results to be produced by this subtask include identification of the unit's organic requirements in terms of users, needlines (both interunit and intraunit), needline characteristics, desired/required telecommunications means, and communications channel requirements.

Subtask 3 will examine identified areas that require communications support, to determine if special communications subsystems may be needed to satisfy particular requirements. These areas must first be identified and their specific requirements determined before various means can be proposed and evaluated. The provision of a separate communications subsystem must be justified; it must consider the specific demands for service, the applicable measures of effectiveness, and available alternate methods of support.

Several sources will be used to identify areas of communications support and their requirements, to include:

- On-site development of minimum essential CE requirements with cognizant agencies (e.g., Air Defense Agency);
- Analysis of pertinent documents:
  - Basic derivative studies and CE annexes
  - Doctrinal concepts for employment of various weapons
  - Technological forecasts
  - Planning documents and studies;
- Visits to PMOs, obtaining requisite information by:
  - Interview
  - Examination of support system documentation;
- AMC Electronic System Procurement Conference.

Specific subsystems considered candidates for communications requirements analysis in this subtask include:

- TOS
- TACFIRE
- CS3
- Air Defense (TSQ-73, SAM-D, Chaparral/Vulcan, etc.)
- Lance
- Pershing
- ATMAC
- Weather
- TACASA.

Published information on these, and other subsystems projected for fielding in the mid range time frame, is expected to be obtained through the INTACS COTR.

As these subsystems are identified and their communications requirements determined, these requirements will be analyzed with respect to the capabilities of the organic communications support to determine the adequacy of service. Where necessary to provide required service, additional communications subsystem networks will be configured and evaluated with SIMCE in a manner similar to network sizing.

The results to be produced by this subtask include the following:

A set of network topologies that represent the additional communications support subsystems;

Accompanying lists of communications requirements data elements that describe in detail the capability needed by these subsystems, identifying the users and the type and amount of traffic to be carried.

Subtask 4 will assign specific communications resources to establish communications networks, special communications subsystems, and organic capability, in accordance with established requirements.

The assignment procedure will vary with the particular area of communications support. Multichannel equipment will be assigned based on the node and link configurations peculiar to each network. The equipment must then be associated with proposed cognizant signal organizations. Personnel requirements will then be determined for these units. Specialized communications subsystems will be developed in a similar manner. The procedure for determining organic requirements leads almost directly to resource selection.

Once resources have been assigned to typical units in the force model, locations can be obtained by referencing the deployment. This assignment step will enable development of the inputs required for the effectiveness, cost, sensitivity, and EMC/EMV analyses in the subtasks that follow.

The effort involved in this and subsequent tasks requires a communications resource data base and efficient methods of access to satisfy the multiple demands for such information throughout the course of the study. The large number of nodes, units, equipment types, and alternative concepts will generate a substantial amount of manual work.

The output of this task will be the candidate communications support systems described in terms of the elements listed below. They will be considered tentative configurations, pending the outcome of the EMC/EMV and cost and effectiveness analysis to be conducted in the following subtasks:

- Identify users by name, unit, echelon, and location;
- Identify the number, nomenclature, function, characteristics, and cost of each type of equipment;

- Identify and configure the radio nets, multichannel subsystems, and special subsystems for each candidate system in terms of users, user/equipment assignments, and user/equipment interconnectivity;

- Define the connectivity and configuration procedures by which the communications equipment is operationally deployed;

- Define the operational procedures and techniques under which the system will be required to operate;

- Identify the quantity and type of personnel required to maintain and operate the system.

The iterative nature of this task is indicated in Figure 2.0-1 by the feedback loop from the output of the system effectiveness analysis (Step 6) and tradeoff analysis (Step 8). Feedback data will include the design deficiencies and limitations identified for each option, and will indicate the need for a revision/modification of the particular candidiate system design.

2.3 COMPUTER SIMULATION ANALYSIS

The two computer simulation models (CASE and SIMCE) will be used to evaluate the following measures of effectiveness:

- Grade of service
- Speed of service
- GOS loss due to nodal destruction
- Ability to adapt to various ratios of traffic types.

Section 2.6 outlines the manner in which the MOEs will be used in the INTACS evaluation. Appendix A defines these MOEs, and in four specific instances, refers to the use of the network models for their evaluation.

2.3.1 Evaluation of Grade of Service

Both SIMCE and CASE will be used to evaluate GOS. It is expected that each will reinforce the other model, and if this is true, the results of the CASE analysis will be used for the MOE. Each model has features common to the other and features not contained in the other. Thus, evaluation by both models will ensure complete consideration of system contributing factors to GOS. Both models evaluate COS for TP and TTY traffic; SIMCE also computes GOS for data, and is being enhanced by the Army to compute GOS for net radio.

2.3.1.1 CASE

For TP traffic, CASE will simulate the generation of messages and count the number of blocked messages. GOS is calculated as the probability that a message is not blocked. Blockage occurs in any of the following instances:

- An operator, or plug, is not available at one of the nodes along the route;
- A link channel is not available;
- A loop channel is not available between the node of destination and the unit of destination;
- The TP is busy at the unit of destination.

CASE simulates automatic switchboards by eliminating the constraining characteristics of manual switchboards, the number of operators, and the operator reaction time. This is accomplished by providing enough operators to immediately service all calls and by specifying a minimal operator reaction time.

CASE permits rerouting in the event of blockage at a node. In this instance, blockage occurs (for system GOS) only if all reroutes fail. GOS for the system (total network) will be computed. Though not part of the MOE, unit-to-unit GOS will be recorded to ensure that satisfactory service is provided to every user.

CASE simulates TTY traffic in a separate model. Messages are not blocked, but remain in queue until a connection is successfully established for transmission. A message completion rate is calculated for the system by dividing the total number of completed messages by the total number of messages generated. The difference between these two numbers is accounted for by the messages remaining in queue or still being processed at the end of the simulation. No messages are assumed lost. This ratio is considered the GOS for TTY traffic.

2.3.1.2 SIMCE

SIMCE provides link GOS for the following circuit types:

- Data, common user, secure
- Data, common user, nonsecure
- TP, common user, secure
- TP, common user, nonsecure
- TTY, common user, secure.

No actual simulation is performed for TP, TTY, and data traffic. GOS is calculated for common user circuits only, using the Erlang B formula and considering traffic requirements and link capacities.

SIMCE considers the command network separately from the area network, and considers Theater Army separately from Corps and below. Thus, four separate runs are required to obtain GOS for the entire system. System GOS is obtained from link GOS when the links are weighted according to traffic requirements.

GOS is also provided for net radio by SIMCE enhancement, a call-by-call simulation of a net radio system. First, the model provides typical unit single-channel needlines by mode, precedence, frequency, length, and purpose (e.g., TUN 6 to TUN 7, voice, 6 routine messages, average length 40 seconds, administrative). Communications analysts will identify the single-channel nets available to each unit and specify the net to be used for each needline. SIMCE randomly generates the appropriate number of messages for each net for the time period to be simulated. If the net is not available when the message is to be sent, it enters a queue for that net. At the end of the simulation, statistics are provided by net on the total number of messages that were queued. This provides the GOS.

2.3.2 Evaluation of Speed of Service

Speed of service for TP and TTY traffic can be measured only by CASE. The model does not include store-and-forward switches and does not evaluate speed of service for data. For TP traffic, CASE totals delay time at the node in terms of two factors:

- Queueing time (the waiting time for an available operator or plug; if over 20 seconds, the call is dropped);
- Seize time (the reaction time required by an operator to seize a plug and insert it into the switchboard.

Required input data includes switchboard characteristics, such as the number of plugs. Manual, semiautomatic, and automatic switchboards can be simulated. SOS by precedence is not calculated for TP traffic.

For TTY traffic, CASE totals activity times for message handling by communications center personnel. These personnel are the message center clerk, the clerk who prepares the message for transmission, the transmitting operator, and the receiving operator. Statistics indicating SOS by precedence are provided. This output will be compared with JCS standards to obtain the value of the MOE.

2.3.3 Evaluation of GOS Loss Due to Nodal Destruction

This MOE is the reduction of system GOS due to destruction of the busiest node. SIMCE will be used for the evaluation.

The busiest node will be identified and removed from the network. Units attached to the destroyed node will not be reassigned to another node, since a lengthy time interval would be required by a signal organization to perform this operation. After a node is destroyed, two possible situations exist, depending upon the knowledge of the users of the the system regarding the nodal destruction:

- Foreknowledge - each user in the system is aware of the destruction of the node, and messages are rerouted to avoid that node;
- No foreknowledge - messages are blocked at the destroyed node, and the previously connected units continue to generate traffic.

Normally, most network users will be instantly aware of the total destruction of a node; therefore, foreknowledge will be assumed in the evaluation of this MOE. SIMCE will be run without the busiest node to obtain a new system GOS. This process of identifying and destroying the busiest node and then measuring the impact of that destruction is reiterated until, in the judgement of the communications analysts, the communications system fails to provide minimal acceptable service.

2.3.4 Evaluation of the Ability to Adapt to Various Ratios of Traffic Types

SIMCE will be used to measure the change in GOS when data traffic is increased at the expense of voice traffic.

The system busy hour will be identified from COMSR data. Communications analysts will convert traffic volume by mode to a common denominator, to determine percentages of traffic by mode.

For the purposes of this MOE, once these percentage levels are established, system GOS will be calculated by weighting (according to the percentages) the separately calculated values of GOS by mode. Then the percentage of data traffic will be increased at the expense of voice, and new values of GOS will be calculated for both data and voice. These new values will be used for the calculation of a resultant system GOS. This process will be repeated to develop a curve of GOS-to-percent data.

For the MOE, data will replace voice on a one-to-one basis. However, this ratio will be varied in a sensitivity analysis.

2.4 COST ANALYSIS METHODOLOGY

The cost analysis will produce the cost information and estimates required in Tasks V, VI, and VII of the INTACS program. The objectives of this analysis are to:

- Provide the system designers with an initial evaluation of the likely life-cycle costs of the alternative system designs and an identification of those factors that contribute to significant cost differences among the alternatives;
- Provide the decision-maker with a ranking of the alternatives on the basis of their life-cycle costs.

Basic assumptions and guidelines used in developing the cost analysis methodology are presented, along with two cost approaches: one aimed at estimating total life-cycle costs of alternatives to aid in selecting a

preferred concept, and one to aid in programming, budgeting, and controlling the preferred alternative system concept. These approaches are discussed fully in Subsections 2.4.1 and 2.4.2, respectively.

The methodology presented in this section has been developed in accordance with USACDC Pamphlet 11-1 and AR 37-18. Cost methodology, cost factors, and CERs used, and formats for presentation of cost data, will be continuously reviewed by a US Army cost analysis activity to be designated by the COR. Cost estimates developed for use in the cost effectiveness analysis will be provided to the same US Army cost analysis activity for review and validation.

Task V will develop a candidate communications system for each alternative concept and perform cost, effectiveness, and sensitivity analyses to recommend a preferred system. Task VI will produce a detailed communications support plan based on the Government's selection of a preferred system. For this plan, manpower and training costs for the specified organizations are required, along with adjusted procurement and inventory costs (based on identified equipment needs and inventory shortfalls) to aid in refining the materiel program. A subset of the described LCC methodology will be used to determine these costs.

In Task VII, yearly costs will be required for programming, budgeting, and control purposes. The methodology for time-allocated costing will be used to produce these cost estimates. The following assumptions and guidelines were used during the development of the cost methodology and are recommended for application in Task V:

- In accordance with the guidelines set forth in DoDI 7041.3, all R&D, investment, and operating costs will be expressed in current fiscal-year dollars. Discounting will be based on an annual rate of 10 percent, as specified by DoDI 7041.3. Discounting is necessary if costs incurred in future years are to be expressed in current fiscal-year dollars;

- Costs incurred prior to the current fiscal year will be considered sunk, and will not be included in LCC calculations. While not included in the LCC, the sum costs will be provided for information;

- Baseline costs will be analyzed using an "average" (expected value) estimate;

- Learning curves will be applied to production cost estimates to adjust for quantity production where historical unit-cost estimates are based on other than expected production quantities;

- Past experience with communications systems studies have shown that, compared to the life-cycle cost of the whole system, the salvage value of the equipment being phased out is negligible, and therefore will not be considered;

- Peacetime operations will be used as a baseline in calculating operating costs;

- Costs of existing facilities and equipment will be included only when the asset has planned alternative use or is intended to be sold (the fair market value will be used to cost such assets);

- Cost uncertainties will be addressed through sensitivity analysis to determine changes in total LCC produced by a deviation in input.

2.4.1 Approach to Life-Cycle Costing

It is a well-accepted premise that, in comparing cost of alternatives, one must consider all costs incurred over the lives of the alternatives rather than just the initial outlays or procurement costs. If costs and benefits of the alternatives are reasonably well-known and can be quantified in some common unit (dollars), one can choose an alternative on the basis of cost differences. The costs and benefits common to all alternatives may be ignored as irrelevant to the decision to be made.

In Task V, however, the alternatives do not offer benefits (e.g., effectiveness) that can be quantified in terms of dollars. It is possible, moreover, that a large fraction of total system costs are not common among alternatives; therefore, for ease of computation and to reduce the chance of omitting a cost difference, all life-cycle costs for each alternative will be considered.

Costs common to alternatives will reduce the computational workload, since they need to be computed only once for the baseline concept and are then available for costing of the alternative concepts.

The structure of the LCC model has been determined by two factors: the form of the required output and the availability of current and historical information as input. The total LCC is broken into the following three basic categories:

- Research and development (R&D) cost
- Investment cost
- Operation and maintenance (O&M) cost.

Cost breakdown structures for these categories are presented in Table 2.4-1. Appendix B provides the specific formula, cost-estimating relationships (CERs), or criteria used to estimate each cost element in the LCC model. The cost data base required by the LCC model is addressed in Subsection 2.4.3, and applicable documentation is listed in Appendix C.

TABLE 2.4-1
Cost Category Summary

Research and Development Cost	Investment Cost	Operation and Maintenance Cost
• Advanced Development – Contractor – Government • Engineering Development – Contractor Program management Engineering Fabrication Contractor development tests Test support Industrial facilities Producibility engineering and planning Documentation General and administrative Fee Other – Government Program management/support Test site activation Government tests Government-furnished equipment Other	• Nonrecurring Investment Cost – Inventory introduction – Initial provisioning (spares and repair parts) – Initial tooling and test equipment – Instructor training – Initial production facilities • Recurring Investment Cost – Total hardware cost – First destination transportation cost – Initial training – Site activation – Acceptance test – Transportation from first destination to user	• Equipment Operation and Maintenance – Pay and allowances for operators – Pay and allowances for maintenance personnel – Replacement training – Repair parts – Integrated logistical support Inventory maintenance Inventory holding Transportation charges to overhaul – Depot rebuild • Vehicle Operation and Maintenance • Generator Operation and Maintenance • Air Conditioner Operation and Maintenance • Contractor Maintenance • Transportation Services • Equipment Wearout • Indirect Operating Costs

Based on the CERs presented in Appendix B, estimates of the life-cycle cost of each alternative will be developed. The costs of the alternatives will be compared, and those system characteristics that contribute to cost differences will be identified.

The results of this analysis will be presented to the system designers. Particular emphasis will be placed on identifying those system characteristics that contribute to major cost differences among the alternatives. Based on these results, the designers will attempt to modify the initial designs to reduce costs. As modifications are developed by the designers, their effect on life-cycle costs will be calculated by the cost analysts. This iterative process will continue until the designers believe system costs are at their lowest values consistent with sound engineering practice, operational requirements, and effectiveness considerations.

2.4.2 Approach to Time-Allocation of Costs

Once a preferred communications system support plan has been defined, it is necessary to develop a schedule and procedure to implement the plan. Time-oriented cost estimates are necessary for budgeting and programming funds to control the implementation process. The objective of Task VII is to develop this implementation plan for the preferred concept, and the time-allocation cost procedures described below are designed to supply needed cost estimates.

The time-allocation cost model was designed for producing budgetary cost estimates. The inputs available to the model are similar to those for the life-cycle cost tradeoff model. The basic inputs consist of the detailed time-phased implementation and support plans containing required equipment, manpower, and materiel, plus actions required to field the system on a year-by-year basis. The data base available is basically the same as that for life-cycle costing.

The basic individual elements identified in the life-cycle cost section (Table 2.4-1) also represent the basic components of budgetary costs. More aggregate budget classifications do not coincide, however, with the major life-cycle cost categories.

Budget classifications are obtained from DoD Manual 7110-1-M, while Table 2.4-2 contains a list of applicable budgetary functional titles and their subdivisions. Not all of the subdivisions will be relevant to the communications support plan being considered, but all relevant life-cycle cost elements will be aggregated into one of the functional divisions, subdivisions, or lower-level budget activities.

While the output of the time-allocation model must be useful in budgeting and control, it need not be in final form for submittal to the DoD budget. The output of the model will not, in general, be in the form

TABLE 2.4-2
Relevant Budget Functional Titles
and Their Subdivisions

- Military Personnel
  - Active forces
  - Reserve forces
- Retired Military Personnel
- Operation and Maintenance
- Procurement
  - Aircraft
  - Missiles
  - Ships
  - Combat vehicles, weapons, and torpedoes
  - Ordnance, vehicles, and related equipment
  - Other procurement
- Research, development, test, and evaluation
  - Military sciences
  - Aircraft
  - Missiles
  - Military astronautics
  - Ships and small craft
  - Ordnance, combat vehicles, and related equipment
  - Other equipment
  - Program-wide management and support
  - Emergency fund
- Military Construction

of budget program elements, but rather in the form of components of these program elements and functional categories that can be aggregated for budgetary purposes. These outputs will be in current-year dollars and on a year-by-year basis. They must then be inflated or reduced by appropriate price-index factors for budgetary purposes or discounted by the appropriate factors and summed to give total discounted costs.

The following is a list of time-allocation cost model outputs for each year required for budgetary purposes:

- Test and evaluation costs
- Training costs
- Equipment procurement costs
- Research and development costs
- Manpower costs
- Operating costs
- Logistical support costs.

The equations required to compute these outputs are given in Section 2.0 of Appendix B.

2.4.3 Cost Data Base

The data base required in the life-cycle costing procedure consists of numerous documents available at Martin Marietta, Booz-Allen, and the U.S. Army Electronics Command at Fort Monmouth, New Jersey, as listed in Appendix C. These documents generally contain necessary unit cost estimates, personnel pay and training rate schedules, equipment descriptions, and cost factors and CERs for estimating relevant cost elements for each equipment and personnel type. In addition to the information contained in the documents listed in Appendix C, data from concurrent tasks, Government-furnished documents, and contractor bids and estimates will also be used as sources of cost estimates and information. Each relevant cost element will be estimated using the best available data.

A review of the equipment lists prepared during Task IV shows that cost estimates for most of the equipment will be directly available or can be derived on the basis of past experience with items of similar nature and complexity. If an estimate is based on analogy, the items used as a data base will be documented along with a summary of assumptions used, differences between the analogous items and the item estimated, and how such differences were treated.

For most cost estimates, some degree of uncertainty will exist; therefore, the cost estimates will be stated in terms of the most likely value, the lowest value, and the most pessimistic (highest) value. A statement that identifies areas of uncertainty and the degree of uncertainty associated with the estimate will also be included.

2.4.4 Cost Sensitivity Analysis

In general, sensitivity analysis is a means of considering uncertainty. In Task V, some of the input parameters (e.g., cost factors and estimates) will be fairly well-known, while others may consist of the "best guess" over a wide range of possible values. The results of the baseline analysis using best estimates may point out certain key assumptions or input parameters that impact highly on the results. Also, little may be known about a set of inputs, so that estimates may be subject to larger error. These are the assumptions and inputs that must be subject to sensitivity analysis.

Cost sensitivity analysis consists of changing an assumption or an input parameter by a specified amount and determining the effect this has on the estimate of total life-cycle cost. Each sensitivity analysis will consist of selecting the assumption or parameter to be varied, determining the equipment, organizations, and cost categories affected by the change, and calculating the resultant estimated costs for each of the affected categories.

Sensitivity analysis will aid in selecting the preferred alternative by providing the tradeoff analysis with the life-cycle cost of alternative concepts under different sets of assumptions and estimates of input parameters.

Some possible candidate subjects for sensitivity analysis include the number of operators and maintenance personnel required under alternative concepts; unit cost estimates for equipment in the conceptual stage of development; and research and development costs for nonexistent equipment. Specific subjects of sensitivity analysis will be determined in the Task V cost analysis and from Government-provided parameters.

2.4.5 Cost Constraint Methodology

It must be emphasized that the cost constraint considerations do not constitute a "design to cost" procedure, in any sense of the phrase. The INTACS design procedure, in keeping with the INTACS Statement of Work, is by definition unconstrained, inasmuch as the objective is to design and recommend a mid range time frame system that meets the communications support requirements (COMSRs) with maximum effectiveness and at minimum cost. The cost constraint considerations, which are based on guidance provided by the SAG, are included in order that the Army can be assured that the resultant recommended system is fiscally obtainable within a reasonable acquisition period.

Three types of cost constraints will be applied in the evaluation of mid range time frame alternative systems:

- "Ballpark" system cost constraints
- Target system life-cycle cost constraints
- Time-allocated cost constraints.

The relationship between system hardware cost and grade of service will be determined during network sizing. The ballpark system cost constraint applies only to hardware costs; it provides the system designer with the GOS to which he will design.

The second cost constraint provides the system cost analyst, designer, and planner with a target system life-cycle cost, to which the life-cycle cost of the candidate systems will be compared.

The third cost constraint, the time-allocated cost constraint, is the yearly communications budget constraint that will be used in Task VII: MRTF Communications System Implementation Planning.

Five basic steps must be followed in employing these cost constraints within Task V:

- The first step is to determine, by network sizing analysis, the functional relationship between system hardware cost, as dictated by system channel capacity requirements, and grade of service. The COMSRs will remain constant.
- The second step requires the Army to evaluate and select the grade of service to which the MRTF candidate systems will be designed, based on the projected cost/GOS relationship.
- The third step is to design the three candidate systems to meet this grade of service.
- The fourth step is the test and refinement of candidate system designs to the life-cycle cost constraints to meet the task objective of "maximum effectiveness at minimum cost".
- The fifth and final step is the development of the mid range time frame implementation plan based on the annual cost constraint.

2.4.5.1 Ballpark Cost Constraint

As stated previously, the ballpark system design constraint is defined and determined within the network sizing task. The principal tool used in this task is the SIMCE computer model. To conduct this analysis, three basic inputs are used:

- Typical units are selected from the force structure for evaluation. (The typical units will be selected from the three types of force units: combat, combat support, and combat service support.)
- The COMSRs are input to the model.

- The SIMCE model is then run, varying the input grade of service required between units. Based on this sequence of runs, channel capacity versus GOS curves are developed.

Concurrently, for each of the typical units selected, the unit's capacity to transmit/receive information (as measured by the number of terminal I/O devices that he possesses) is determined in erlangs. The quantitative cost of the typical unit's terminal I/O equipment is determined. In addition, the percentage of the total unit communications hardware cost is determine. The relationship between the channel capacity (in erlangs) and cost is established and averaged over the set of typical units, and the relative-cost/present-cost versus GOS curves are developed. These curves then establish the functional relationship between the basic three variables: relative cost in dollars, grade of service, and the COMSRs (where the COMSRs, as stated earlier, remain constant).

The relationships are provided to the Government for a decision on the design GOS that the mid range time frame systems are to meet.

2.4.5.2 Life-Cycle Cost Constraint

Testing and refinement of candidate mid range time frame systems to a life-cycle cost constraint depends upon the definition of the Government-provided cost constraint. As a minimum, the life-cycle cost constraint must be a target figure with a variance in percent. The total life-cycle cost must be broken down into types of funds (RDT&E, MPA, PEMA/OPA, OMA) by cost limitation. In Subtask 4, the cost analyst determines and compares the cost of the candidate systems, identifying excessive costs and areas of system design which attribute to these costs. Based on the results of the cost analysis, the system designer refines/modifies the areas of system design that will reduce/minimize cost. The system designer then resubmits his design to the cost analyst for comparative analysis.

2.5 RISK ANALYSIS METHODOLOGY

A risk analysis is performed because the selection of a preferred alternative based only on consideration of cost and effectiveness figures could lead to erroneous conclusions. This possibility exists because the implementation of an alternative system may require development of new equipments not currently available in the civilian or military inventories.

In carrying out such development, it is possible that equipment with the required characteristics cannot be developed within the time period involved. The probability that this may occur is related to the value of the risk figure of merit, which is designed to flag potential problems in the realization of an equipment. Based on an examination of the equipment list approved by SAG, no technical risk is associated with the equipment to be considered for the mid range time frame (i.e., the risk is considered to be zero). All equipment is, at present, technically feasible, and time is not considered a risk in terms of equipment availability for the MRTF.

2.6 SYSTEM EFFECTIVENESS ANALYSIS

This section provides the fundamental approach taken by the study team in establishing a sound methodology and generating reasonable criteria that will permit the orderly evaluation, comparison, and ranking of proposed alternative concepts.

The section summarizes the areas of effectiveness, aspects, and measures of effectiveness proposed for employment in the analysis of INTACS alternatives. Each area is presented, along with the aspects directly related to the evaluation of the INTACS alternatives. Quantitative measures of effectiveness (MOEs) are derived for those aspects that can be quantified.

Qualitative MOEs are proposed for aspects where quantification is impracticable. In these instances, a systematic (albeit qualitative) procedure is proposed for evaluating each alternative. With reference to qualitative aspects, appropriate questions will be posed, the answers to which are expected to distinguish the alternatives. Responses will be converted to a dimensionless value within a predetermined scale (e.g., 1 to 10) assigned for formal group concensus and based on:

- The difference between the proposed alternative and the baseline system;
- Subjective opinion on the increase or decrease in system effectiveness resulting from this difference.

The aspects and areas of effectiveness result in quantitative and qualitative assessments of the system's capabilities. These assessments, which have a multitude of dimensions, must be reduced to the single, dimensionless quantity used to rank-order the communications system concepts. This single number also facilitates comparison of a large number of unrelated pieces of information on each alternative. The single quantity, or system utility, is not meant to be the final result of the effectiveness analysis, but to be used in conjunction with two other outputs: sensitivity analysis and the identification of underlying factors that contribute to the system utility. Together, these outputs will be employed in the rank-ordering of the system alternatives.

In ordinary terms, the basic approach can be stated simply as an endeavor to quantify areas and aspects (if feasible), and resort to qualitative scaling of aspects where quantification is not feasible (relying on the judgement of qualified experts). The final step in the approach will be the coherent use of the measurements by a system utility measurement procedure to arrive at a figure of merit for determining priorities of alternatives.

2.6.1 Areas, Aspects, and Measures of Effectiveness

Areas of effectiveness are broad categories of capability relevant to the system alternatives to be evaluated and the operational situations within which they are to be analyzed. Fourteen such areas were specified for analysis:

- Quality of service
- Mobility
- Transportability
- Vulnerability
- Survivability
- Flexibility
- Reliability
- Logistical support
- Security
- Operability
- Standardization
- Maintainability
- RF spectrum requirements
- Electromagnetic compatibility.

After determining the pertinent areas of effectiveness, aspects within each area were selected on the basis that:

- The aspects are important considerations within the area;

- Evaluation of the aspects will distinguish the concepts at the system level or at the echelons of brigade, division, or higher.

Once the aspects were identified, consideration was given to the specific features within each aspect that contribute significantly to evaluation of the aspect and differentiation of the concepts. If the feature could be quantitatively measured (with data and models available to this project), a quantitative MOE was specified. If the feature was either qualitative in nature or required subjective estimation of a quantitative value, then the methodology for highlighting the feature was specified. Communications analysts will assign a qualitative MOE to each concept, indicating the resultant degree of improvement or degradation in system performance (from the baseline concept). The MOEs are listed in Subsection 2.6.2.3 and defined in Appendix A. Also, Appendix A specifies the estimation techniques and assumptions employed in the development of each MOE.

Some MOEs will be evaluated by examining performance in specific situations provided in a communications-oriented scenario. The scenario involves a fixed deployment of a Theater Army in a mid-intensity combat environment in Europe. Communications needlines have been determined, user

communication requirements have been estimated, and unit and system busy hours have been identified. Each concept will be sized to satisfy communications requirements based on this scenario. Situations in the scenario which provide a critical point and best time for evaluation of the MOE will be identified. These situations may vary in time for the same MOE if the different echelons have their critical events (or busy hours) at different times. Some MOEs will be evaluated by the SIMCE or CASE models, taking scenario communications requirements and resultant equipment deployments as input.

Additionally, several MOEs are based on outputs provided by the electromagnetic compatibility/electromagnetic vulnerability (EMC/EMV) analysis conducted by the Electromagnetic Environmental Test Facility (EMETF) of the U.S. Army Electronic Proving Ground (USAEPG). The analysis will be run on an Army-developed test bed that is based on a mid-intensity combat scenario with appropriate friendly and enemy force models used in conjunction with statistical terrain propagation characteristics.

2.6.2 Effectiveness Utility Method

The purpose of this section is to explain the development of effectiveness utility methods and to illustrate their use in conjunction with measures of effectiveness in determining an overall figure of merit for a given system alternative. This section endeavors to answer the following questions:

- How are utility values determined?
- How will utility values be used?

The importance of these two steps should not be overlooked. Establishment of a coherent relationship between utility values and measures of effectiveness to achieve credible figures of merit will significantly impact the effort to identify the preferred system.

In a theoretical sense, utility is a dimensionless number assigned to each system alternative indicating its relative effectiveness with respect to particular measures of effectiveness. The concept of utility serves two purposes; first, it reduces quantitative and qualitative assessments of different dimensions to a single dimensionless quantity, which is used as a figure of merit. Secondly, it provides a vehicle for indicating actual effectiveness differences that result from differences in quantitative assessment of system parameters. The FOM, as a representation of system effectiveness in terms of a single number, facilitates cost/effectiveness tradeoff analysis and comparison of a large number of unrelated pieces of information on each alternative. The FOM is not intended to be the final result of effectiveness analysis, but only one of the outputs. Sensitivity analysis and identification of the driving forces behind FOM results are also important considerations.

If the methodology for combining diverse measures into a single FOM is to be successful, it should satisfy certain requirements. These are

determined by the nature and ultimate use of the desired output. In the case of INTACS, the requirements are as follows:

- Dimensionless units should be of uniform value;
- The source of FOM differences should be identifiable (all effectiveness analyses will be listed);
- The present communications system should be used as a baseline for comparison purposes only;
- Conversion to utility should be done during the evaluation of each system, so that transformations necessary to achieve linearity can be made;
- The methodology should be understandable to the group making value judgements;
- Implementation should be achievable within the INTACS schedule.

In addition, constraints imposed by the magnitude and depth of INTACS are:

- Some inputs will be subjective;
- Some inputs will be qualitative;
- A value judgement of all MOEs at one time is impractical.

After a review of available reference material and previous work, a hybrid approach that satisfies all requirements and constraints was synthesized. This methodology provides an acceptable means of obtaining an FOM, or system utility, for each alternative. The steps to be completed in generating an FOM are:

- Allocation of utility
- Evaluation of each alternative
- Calculation of FOM.

These steps are explained in the subsections that follow.

2.6.2.1 Utility Allocation

The allocation process is a method by which the total utility is divided among the various MOEs in accordance with their relative contribution to communications system effectiveness. The steps required to complete the allocation are:

- Designate numerical value of total utility
- Allocate total utility to areas
- Allocate each area utility to its aspects
- Allocate each aspect utility to its MOEs.

Initially, an appropriate number of utility units, or utiles, must be designated for the total utility. This is an arbitrary number selected by the analyst to provide a convenient degree of resolution.

To limit the number of elements that must be considered at one time, distribution of total utility is separated into three stages. The first stage is to distribute the total utility among the areas of effectiveness (AOEs). The basis for allocation is the relative importance of each communications system factor under consideration. After the initial allocation by group concensus, a thorough review of all the relative values may dictate further modification. Of the utmost importance is that the group fully understand the concept of utility and be cognizant of all the implications contained in the final product. At this point, each AOE will have an assigned utility, and the sum of all these area utilities will be equal to the total utility.

In the second stage, each area utility is subdivided into aspect utilities through the same group concensus allocation process. Finally, in the third stage, the MOE utilities are derived from aspect utilities by using a similar methodology.

This procedure permits uniform units of utility to be maintained at every stage, which enables direct comparison of components within the network. An example is presented in Figure 2.6-1. In this figure, 12 measures occur at the MOE level, allowing a reasonable choice for total utility of 120 utiles. A typical allocation, which finds seven measures on the aspect level, is shown in the figure. Those areas of interest are located on the area level, immediately below total utility. Therefore, in effect, the figure depicts 12 MOEs grouped into seven aspects that are reduced to three area groups, all comprising the total.

Since the utility units are uniform throughout, the relative value may be determined for any component. For example, to illustrate this point, note that the MOE at block 2/1/1 was awarded 25 utiles, and is considered more important than the entire area (block 1) at a higher level with only 20 utiles.

The actual allocation of utility has been performed by the Army; it was based upon an analysis and synthesis of results from the allocations of four independent teams of active Army officers. The results are provided in Appendix A. These results will be analyzed to determine whether or not the number of MOEs may be reduced. If an MOE has little effect on the figure of merit, it is a candidate for elimination. An example of this approach is presented in Appendix F.

2.6.2.2 Evaluation of Alternatives

Once a utility value is established for each MOE, the communications systems under consideration will be rated. The methodology will consider one MOE at a time, and will evaluate the performance of each system

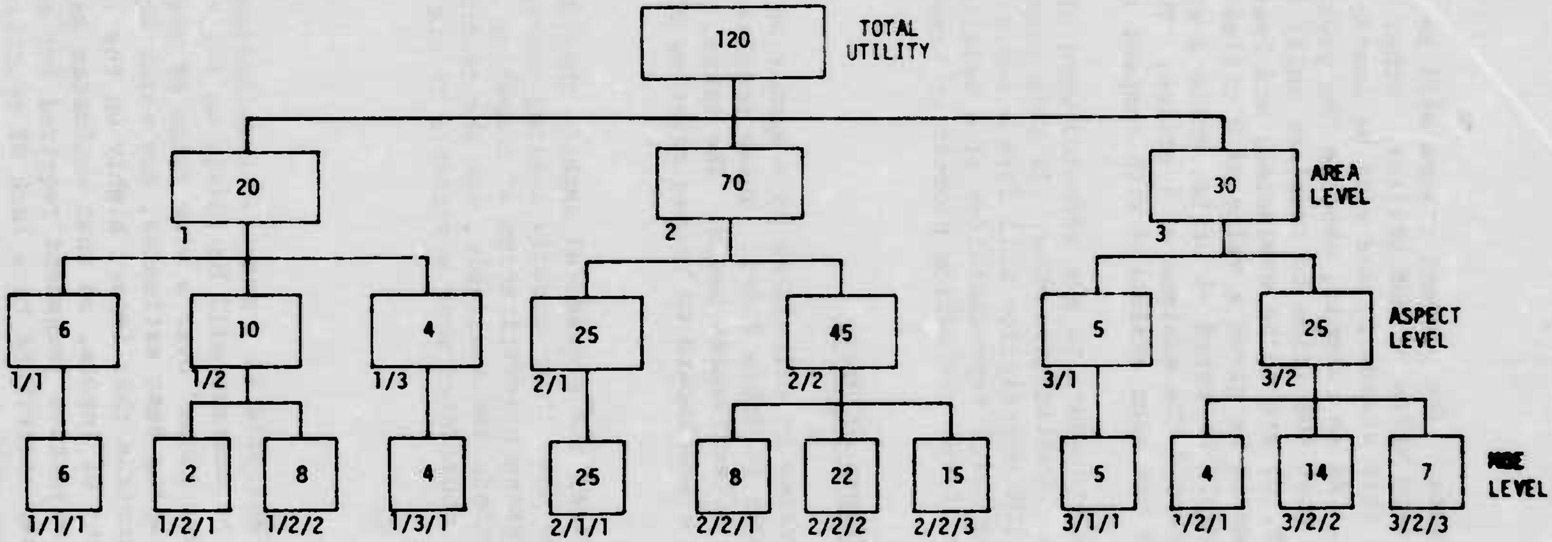

FIGURE 2.6-1 Utility Allocation Scheme

with respect to that indicator. The present system will be adopted as a baseline and assigned the zero value of MOE utility. Other alternatives will be judged relative to this standard, and will be awarded appropriate utility by group concensus. As an example, observe the problem outlined in Figure 2.6-2. Consider that MOE (time to complete call) is allocated 4 utiles; three systems (A, B, C) are to be evaluated; and System A is the present system. System A would be given a value of 0 utiles. Slightly lower effectiveness in System B would be rated -1 utile, while a significantly better System C would be awarded the maximum of 4 utiles. The process continues until each system has been evaluated with respect to every MOE.

At this point, the procedure is not affected when alternatives are evaluated relative to the qualitative MOEs. In this case, the answers to questions stated in the MOE description will form a basis for comparison, with the present system still representative of a baseline and assigned a zero utility. An example of the evaluation process is presented in Appendix E.

2.6.2.3 Determination of Figure of Merit

The FOM for each system is calculated by a summation of its performance on all MOEs, as shown in Table 2.6-1. These results are used to rank the alternatives on an effectiveness basis. The table, in the simple format shown, will serve as a scoreboard to record relative FOMs and subsequent rankings.

This section summarizes the procedural aspects that describe how the measurement tools will be used in an orderly scaling process to determine relative values and a system prioritization of competing alternatives. Other utility measurement methods are available, but the techniques explained in this section were considered most applicable to the problem at hand.

2.7 SENSITIVITY ANALYSIS

In general, sensitivity analysis is a means of considering uncertainty. In Task V, some of the input parameters will be fairly well-known, while others may consist of the "best guess" over a wide range of possible values. The results of the analysis, using best estimates, may point out certain key assumptions or input parameters that impact highly on the results. Also, little may be known about a set of inputs, so that estimates may be subject to error. In addition, the subjective judgement required for qualitative MOEs and utility allocation may contribute to a lack of precision. These are the assumptions and inputs that will be subject to sensitivity analysis. An example of this analysis is presented in Appendix E.

MOE UTILITY - FOUR UTILES

System	MOE (sec)	Utility
A (baseline)	3	0
B	4	-1
C	1.1	4

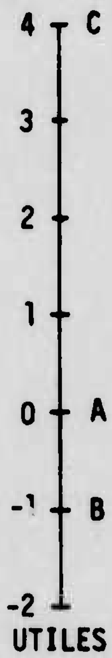

FIGURE 2.6-2 MOE Conversion to Utility

TABLE 2.6-1
Figure of Merit and System Ranking

System	Quantitative MOE Utility				Qualitative MOE Utility			Total (FOM)	Rank
A	XX	XX	XX	XX	XX	XX	XX	XXXX	X
B	XX	XX	XX	XX	XX	XX	XX	XXXX	X
C	XX	XX	XX	XX	XX	XX	XX	XXXX	X
D	XX	XX	XX	XX	XX	XX	XX	XXXX	X

2.7.1 Parameter Sensitivity Analysis

Parameter sensitivity analysis consists of changing an assumption or input parameter by a specified amount and determining the effect this has on the FOM. Each sensitivity analysis will consist of selecting the assumption or parameter to be varied, determining the MOEs affected by the change, and calculating the resultant FOM. A suggested approach is to vary the input parameter by 5 percent of its value and determine the percentage change in the FOM. The parameter that produces the greatest change in the FOM is the most sensitive.

Sensitivity analysis will aid in selecting the preferred alternative by providing the tradeoff analysis with an FOM for alternative concepts under different sets of assumptions and estimates of input parameters. Sensitivity of the FOM to the qualitative MOEs will be addressed. Specific input parameters to be varied include the following:

- Number of nodes in the area system
- Multichannel routing schemes in both SIMCE and CASE
- Hold time (message length)
- Busy-hour traffic.

2.7.2 Utility Allocation Sensitivity Analysis

The purpose of this analysis is to determine the effect of a slightly different utility allocation on the figure of merit for each system. To illustrate the importance of this concept, consider the evaluation of two alternatives (Systems A and B) outlined in Figures 2.7-1 and 2.7-2. Two MOEs are used; System A offers significant improvement in the parameter assessed by MOE-1, and slight improvement with respect to MOE-2. For System B, the data is slight improvement in MOE-1 and significant improvement in MOE-2. Assume that 10 utiles are allotted: an initial allocation of 8 utiles for MOE-1 and 2 for MOE-2 is made. After the evaluation shown in Figure 2.7-1, System A would be the preferred alternative, with 9 utiles, compared to 6 utiles for System B. If a second allocation is made with MOE-1 reduced to 4 utiles and MOE-2 increased to 6 utiles, the ranking is changed as shown in Figure 2.7-2. System B is highest, with 8 utiles, compared to 7 utiles for System A, thus reversing the previous ranking.

Obviously, the allocation process is not exact. An MOE could vary in utility if a different group made the allocation, or even if the same group repeated the process on a different occasion. It is important to determine whether or not a change in the allocation could affect the ranking, and this is the purpose of utility sensitivity analysis.

One part of the sensitivity analysis is to vary each MOE utility a fixed percentage and examine the effect on ranking. This will be done for each system to see if the ranking changes under the most adverse combination of variations. A second task is to establish, for each system, an allocation that allows that particular system to rank highest. The feasibility of each allocation will be discussed in the Task V Final Report.

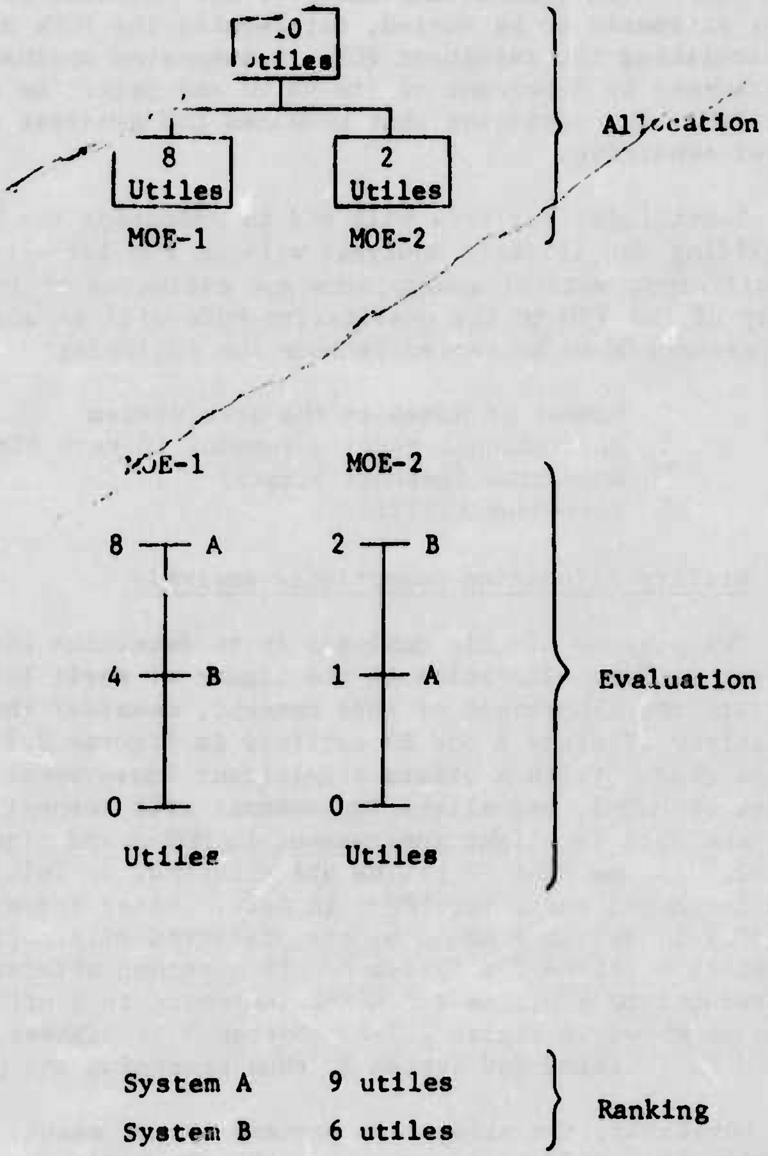

FIGURE 2.7-1 Initial Allocation

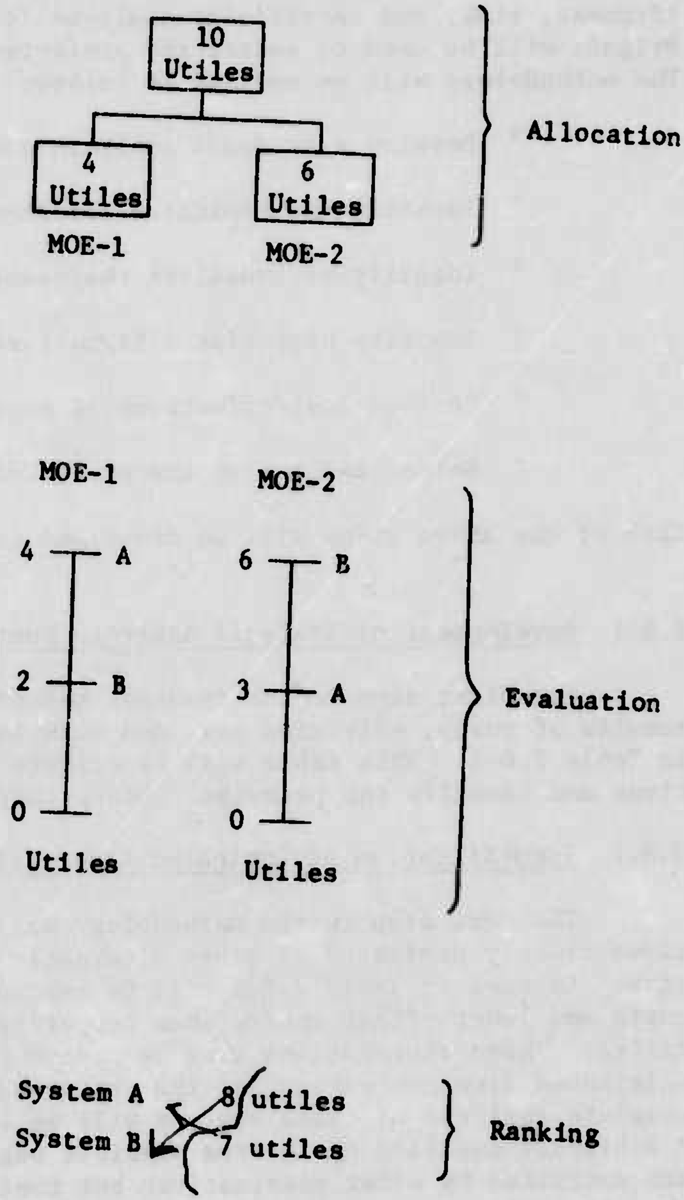

FIGURE 2.7-2 Second Allocation

2.8 COST/EFFECTIVENESS TRADEOFF ANALYSIS AND RANK-ORDERING METHODOLOGY

The final phase of the application of the cost/effectiveness methodology will be the development of a tradeoff procedure oriented toward the selection of a preferred alternative. The results of the cost, effectiveness, risk, and sensitivity analyses for EAD, Division, and Separate Brigade will be used to select the preferred alternative at each echelon. The methodology will be applied as follows:

- Develop a tradeoff analysis summary table
- Identify the dominated alternatives
- Identify alternatives that exceed cost thresholds
- Identify high-risk alternatives
- Perform cost/effectiveness sensitivity analysis
- Select and refine the preferred alternative.

Each of the above steps will be discussed in the remainder of this section.

2.8.1 Development of Tradeoff Analysis Summary Table

The first step in the tradeoff methodology will be to arrange the results of costs, effectiveness, and risk into a summary table, as shown in Table 2.8-1. This table will facilitate the differentiation of alternatives and identify the principal issues that contribute to these differences.

2.8.2 Identification of Dominated Alternatives

The next step in the methodology will be to identify the alternatives clearly dominated by other alternatives in cost, effectiveness, and risk. Entries in Table 2.8-1 will be examined, and alternatives with higher costs and lower effectiveness than competing alternatives will be identified. These alternatives will be placed in a group with others that are eliminated from contention for the preferred alternative position, but a complete analysis of these systems will be included in the Task V report. A difficult decision may be the possible segregation of alternatives that are dominated by other alternatives but that contain minimal risk. If this situation occurs, the alternative should be eliminated only if it has considerably greater costs and significantly less effectiveness than other alternatives.

An alternative should not be eliminated if it has the following characteristics relative to the other alternatives:

- Slightly greater cost
- Slightly less effectiveness
- Lower risk.

TABLE 2.8-1
Tradeoff Methodology

Alternative	Effectiveness	Effectiveness Sensitivity	Utility Sensitivity	Cost	Cost Sensitivity	Risk Figure of Merit	Rank
	Advantages Disadvantages MOE	Sensitivity to variation in parameters	Sensitivity to variation in allocation	Life-cycle cost	Sensitivity to variation in assumptions	FOM List risks	Final rank of systems

Alternatives with these characteristics will be examined in the sensitivity phase of the tradeoff.

2.8.3 Identification of Alternatives that Exceed Cost Thresholds

The third step will be to identify alternatives wherein cost differences are so significant as to indicate that the alternative will, in all likelihood, exceed cost thresholds provided by the Army. This step will require consideration of expected acceptable costs for particular equipments. Significant cost differences between alternatives will accrue from the approaches adopted for phase-in/phase-out stages, the number of equipments, and the resources for new developments.

2.8.4 Identification of High-Risk Alternatives

The fourth step in the tradeoff methodology will be to identify those alternatives characterized by high risk along with a low compensating differential in cost and effectiveness as compared to the other alternatives. Those alternatives with high risks, costs below threshold, and relatively high effectiveness will be considered as candidates in the selection of the preferred alternative. Alternatives separated by this step will most likely consist of equipment that will require development programs but not eventually contribute to a decrease in per-unit cost or a substantial increase in effectiveness.

2.8.5 Performance of Cost/Effectiveness Sensitivity Analysis

The fifth step of the tradeoff methodology provides the basis for selecting the preferred alternative from the remaining set. The cost, effectiveness, and risk of the alternatives will be expressed as a percentage of the least cost alternatives. These numbers will indicate the percentage increase/decrease in effectiveness obtained for the percentage increase in cost. The percentage change in risk will also be noted.

2.8.6 Selection and Refinement of the Preferred Alternative

Final selection of a preferred alternative over those remaining will be based on Step 5 of the methodology and a consideration of Table 2.8-1. The results of Step 5 will be the primary consideration, although an examination of Table 2.8-1 will also be necessary, since some special attributes of the alternatives might not be reflected in the analysis.

After the preferred alternative is selected, it will be refined to obtain the optimal system. Weak areas of the system will be identified and improved if possible. The process may involve combining parts of an alternative system with the preferred system to attain the best performance. Once the alterations are complete, the evaluation process will be repeated to validate the changes.

A summary paper will be developed to document the analysis and the rationale behind the selection of the preferred alternative. It will contain the following sections:

- Summary description of the alternatives;
- Results of the analysis as presented in Table 2.8-1;
- Summary of the method by which Table 2.8-1 entries were determined;
- Audit trails of subjective judgement in effectiveness evaluation;
- Rationale to explain the selection of the preferred alternative.

This supporting paper will document the tradeoff methodology.

APPENDIX A
EFFECTIVENESS AREAS, ASPECTS, AND MEASURES

APPENDIX A
EFFECTIVENESS AREAS, ASPECTS, AND MEASURES

1.0 INTRODUCTION

This appendix details the areas, aspects, and measures of system effectiveness that were previously outlined in Section 2.6. The utility allocation for these MOEs is provided in Section 3.0 of this appendix.

The areas of effectiveness are broad categories of system capability relevant to the MRTF concepts that are to be evaluated and to the operational situations in which these concepts are to be evaluated. One or more aspects are identified and defined within each area of effectiveness. These aspects were selected on the basis that they are important facets of the area and are expected to distinguish the concepts at the system or echelon level.

Quantitative and qualitative measures of effectiveness are defined for each aspect. Procedures for evaluation or estimation of the measures are outlined, including identification of any assumptions made. Any requirement for Government-furnished information is also identified.

The term "communications analyst", as used in this appendix, refers to the members of the Martin Marietta/Booz Allen study team. Two types of individuals are covered by this designation:

- Retired Army signal officers who are currently employed by Martin Marietta or Booz Allen and who have been assigned to the INTACS study team;
- Operations research analysts employed by Martin Marietta or Booz Allen and assigned to the INTACS effort.

These individuals will apply the subjective considerations required to make the qualitative evaluations called for in the methodology.

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2.0 AREAS, ASPECTS, AND MEASURES OF EFFECTIVENESS

The presentation technique will be the same for each of the 14 areas, and will contain subparagraphs in a standard ordering, as follows:

- Area of effectiveness
- Aspect of effectiveness (within the area)
- Quantitative measure of effectiveness (within the aspect)
- Estimation procedures for the quantitative MOEs and for the qualitative MOE, if applicable
- Assumptions made and sources of information.

2.1 AREA: QUALITY OF SERVICE

Quality of service is defined as the ability of a communications system to effect successful first-try call initiation in a timely manner and with intelligible message transmission. Quality of service includes the following three aspects:

- Grade of service
- Speed of service
- Information quality.

2.1.1 Aspect: Grade of Service

The grade of service (GOS) is defined as the probability that a given transmission will not be blocked at some point in the path between the transmitting user and the receiving user.

2.1.1.1 Quantitative Measure of Effectiveness

The grade-of-service MOE is defined as the probability that a subscriber's call attempt will not be blocked.

2.1.1.2 Estimation Procedures

Grade of service is determined separately for voice, data, fax, and TTY. It is calculated for each link, and the measure is weighted by the

volume of traffic on each link. The GOS for a particular communications mode is computed as follows:

$$GOS = \frac{1}{\sum_i e_i} \sum_i e_i \; GOS_i$$

where

e_i = total traffic on the i^{th} link

GOS_i = grade of service for the i^{th} link.

GOS_i is determined by CASE for TP and TTY, and by SIMCE for data and net radio. GOS_i for MARTS is computed by using a special queueing algorithm to represent the multiple channels available to the user.

2.1.1.3 Assumptions and Estimation Conditions

The following assumptions and estimation conditions are made:

- The call attempt is made during busy-hour traffic;
- All equipment is operational.

2.1.2 Aspect: Speed of Service

Speed of service (SOS) is the total delay time from the moment the message enters the system until the receiving unit begins to receive the message.

2.1.2.1 Quantitative Measure of Effectiveness

The speed-of-service MOE is defined as the probability that the total delay time of a message is within the acceptable limits for messages of that precedence.

2.1.2.2 Estimation Procedures

For each message transmitted, totals will be accumulated to reflect transmission time, time in queue, and total processing time. From this information, message delay time will be calculated (excluding actual message transmission time). For each mode (except TTY), speed of service will be calculated as the average message delay time.

Four precedences are handled by the CASE model for TTY: flash, immediate, priority, and routine. Message delay will be compared with JCS standards for each precedence. Statistics will be accumulated for each

precedence, to indicate the percentage of messages that have a total delay within the acceptable limits. These four percentages will be averaged to give one value for speed of service for TTY.

2.1.2.3 Assumptions and Estimation Conditions

The following assumptions and estimation conditions are made:

- The call attempt is made during busy-hour traffic;
- All equipment is operational.

2.1.3 Aspect: Information Quality

The degree to which a candidate concept successfully passes messages that meet minimum signal-to-noise criteria for the mode of transmission used is indicated by the EMC/EMV communicability scores. For example, in the communicability subtest, the differing RF S/N ratio and signal strength requirements for an HF receiver to provide adequate speech intelligibility (when used on single sideband circuit) or text intelligibility (as when used on teletype circuits) are taken into account by specifying different minimum signal requirements when used in different modes. In the communicability subtest, the probabilities of satisfactory operation (P(SO)) are evaluated for links between friendly transmitters and their intended receivers without considering interference. The EMC/EMV analysis combines these P(SO) into system effectiveness (SE) scores for net types.

2.1.3.1 Quantitative Measure of Effectiveness

System communicability score.

2.1.3.2 Estimation Procedures

The EMC/EMV communicability output consists of a list of SE scores by net type. The MOE is a weighted arithmetical mean of the SE scores on the basis of the number of nets of the net type and a weighted value for the net type determined by communications analysts*:

$$C_S = \frac{\sum_{t=1}^{T} V_t N_t (SE)_t}{\sum_{t=1}^{T} V_t N_t} \qquad (0 \leq C_S \leq 100)$$

where

C_S = the system communicability score

T = number of different discrete types

* Where applicable, these will be taken from DACE-CMS-E letter of 27 December 1973, Subject: Standards for Weighting Communications and Electronics Nets and Links in Simulated Force Models.

t = a discrete net type, $t=1, 2, 3, 4, \ldots, T$

V_t = value of net t ($0 \leq V_t \leq 10$)

N_t = number of nets of net types t in the system, $N_t = 1, 2, 3, 4, \ldots$

$(SE)_t$ = communicability system effectiveness score for net type t.

2.1.3.3 Assumptions and Estimation Conditions

The following assumptions and estimation conditions are made:

° No jamming or unintentional interference is present in the communicability subtest;

° The predominant factors that affect satisfactory reception of signals are effective radiated power, path attenuation, and receiver sensitivity;

° Cumulative noise in multilink transitions and signal conditioning, pulse shape restoration, etc., are not considered.

2.2 AREA: MOBILITY

Mobility is defined as the capability of the system to permit users to move from place to place while retaining the ability to fulfill their primary mission. It includes the following two aspects:

° Physical setup/teardown time
° Ability to communicate during moves.

2.2.1 Aspect: Physical Setup/Teardown Time

The concepts will be evaluated according to the average time required to set up or tear down critical equipment or assemblages of equipment under normal system conditions.

2.2.1.1 Quantitative Measure of Effectiveness

Physical setup/teardown time.

2.2.1.2 Estimation Procedures

Communications analysts will identify the CE equipment that is considered critical to system performance and that differs among the concepts. Additionally, major assemblages of equipment (e.g., radio terminal set, command center, operations center) will be specified and evaluated.

From setup/teardown procedures for the individual equipment, required man-minutes (by MOS, if appropriate) will be estimated by communications analysts.

The critical path for setup/teardown time for both critical equipment and major assemblages of equipment will be determined by considering the required sequence of events in setup/teardown procedures and the manpower restrictions (e.g., same individual responsible for several pieces of equipment). The time along this critical path is the actual measure of setup/teardown time.

2.2.1.3 Assumptions and Estimation Conditions

For equipment in the current inventory, setup/teardown procedures will be determined from technical manuals.

Communications analysts will estimate setup/teardown times for equipment in R&D based on the setup/teardown times of similar equipment in the current inventory.

2.2.2 Aspect: Ability to Communicate During Moves

The concepts will be evaluated according to the reduced capability and information intelligibility degradation for a unit during movement. Units considered will be of company size or larger.

2.2.2.1 Quantitative Measure of Effectiveness

Reduced communications capability for unit during move.

2.2.2.2 Estimation Procedures

Communications analysts will identify situations in the scenario that dictate the movement of a unit. For the members of that unit, total communications capability (channels/nets available) prior to movement will be noted and compared to the reduced capability during movement. The average percent reduction in capability will be the quantitative MOE. In addition, communications analysts will estimate the degradation of information intelligibility that results from small sector signal variation. This will be in the form of a qualitative MOE.

2.2.2.3 Assumptions and Estimation Conditions

Impact of a unit move on the entire network will be considered in a separate MOE.

2.3 AREA: TRANSPORTABILITY

Transportability is defined as the capability to efficiently and effectively transport a communications equipment complex. Transportability includes the following aspects:

- Size and weight of CE equipment, support parts, and power sources;
- Vehicle requirements of the communications system;
- Portability.

2.3.1 Aspect: Size and Weight of CE Equipment, Support Parts, and Power Sources

The concepts will be evaluated according to the total volume and weight of the equipment and power and support parts required for each subsystem (TROPO, LOS, etc.) and for the entire communications system.

2.3.1.1 Quantitative Measure of Effectiveness

Total volume (in cubic feet) of communications system/subsystem equipment and parts, and total weight (in tons) of communications system/subsystem equipment and parts.

2.3.1.2 Estimation Procedures

The system design effort in Task V will provide TOEs for all units. From these TOEs, CE equipment quantities and types will be obtained. Support parts and power requirements (generators, batteries, etc.) will be identified, as indicated in Subsections 2.8.1 and 2.8.2. Communications analysts will categorize the equipment, parts, and power sources according to the subsystems they support. The total volume and weight for each of these subsystems and for the entire system will then be calculated.

2.3.1.3 Assumptions and Estimation Conditions

The volume and weight for specific equipment, parts, and power sources in the current inventory will be GFI. This information will be estimated by communications analysts for any item in R&D.

2.3.2 Aspect: Vehicle Requirements of the Communications System

The concepts will be evaluated according to the total number and type of transport vehicles required to support the communications system.

2.3.2.1 Quantitative Measure of Effectiveness

Percentage of total transport vehicles (required to provide communications support to the unit) that are organic to the unit.

2.3.2.2 Estimation Procedures

The system design effort in Task V will provide TOEs for all units. These TOEs indicate the equipment and vehicles that are organic to the individual units. Based on volume, weight, time, and other considerations, communications analysts will identify the vehicle requirements of each unit to transport the specific CE equipment used by that unit. These vehicles will be categorized by type (e.g., 1/4-ton and 2 1/2-ton trucks, vans, and trailers) and will be totaled to provide the vehicle requirements of each unit. For each type, the percentage of required vehicles that are organic to the unit will be calculated. (For the system, the percentage of total vehicle requirements organic to the unit will be calculated.) The higher this percentage, the better the value of the MOE.

2.3.2.3 Assumptions and Estimation Conditions

Vehicles not used to transport communications equipment or power sources will be excluded when identifying vehicles organic to the unit.

2.3.3 Aspect: Portability of CE Equipment

The concepts will be evaluated according to the degree of portability of CE equipment. Portability is determined by equipment characteristics and function.

2.3.3.1 Quantitative Measure of Effectiveness

Not applicable.

2.3.3.2 Estimation Procedures

The system design effort in Task V will provide TOEs for each unit within an echelon. These TOEs indicate quantities of types of equipment required for each alternative. After examining size, weight, function, power source requirements, and other features of each type of equipment, communications analysts will assign the CE equipment to one or more of the following nine categories:

- Equipment designed for permanent installation;
- Equipment capable of being used in two or more types of ground installations;
- Compact, lightweight equipment that may be held by one hand, suspended from a belt, or carried in a pocket and operated on the move;

- Compact, lightweight equipment to attach to a helmet or to headgear of some type, and for operation by the bearer;

- Equipment installed and operated from a vehicle whose sole function is to house and transport the equipment (the vehicle(s) must be "part of" the equipment);

- Equipment designed to be transported by one man and not to be operated on the move;

- Equipment designed for packing into individual manloads for transport by a team (not operated while in transport);

- Equipment larger than handheld but designed for operation while being carried by one man;

- Equipment installed in a vehicle designed for functions other than carrying electronic equipment, such as tanks, weapons carriers, etc. The equipment must be capable of operation while the vehicle is in motion.

After completion of this categorization, communications analysts will evaluate portability for the communications system as a qualitative MOE.

2.3.3.3 Assumptions and Estimation Conditions

For equipment in the current inventory, all pertinent features necessary for this evaluation can be obtained from technical manuals. For equipment currently in R&D, this information will be provided by the system designers.

2.4 AREA: VULNERABILITY

Vulnerability is defined as those characteristics of a system that cause it to suffer definite degradation (incapability to perform the designated mission) as a result of having been subjected to a certain level of effects in an unnatural (manmade) hostile environment. Specific factors in vulnerability are susceptibility due to inherent hardware weaknesses, enemy threat, and interceptibility. Vulnerability includes the following aspects:

- Susceptibility to physical destruction (ground/air)
- Susceptibility to direction-finding
- Interceptibility.

2.4.1 Aspect: Susceptibility to Physical Destruction

The concepts will be evaluated according to the likelihood that an enemy can successfully execute destructive physical attack (ground/air) on major points in the communications system. This will include consideration of inherent hardware weaknesses, susceptibility to physical or electronic detection, likelihood of enemy attempt to attack, and capability of defense against enemy attack. Entire nodes, selected functions at a node, and power sources will be analyzed in terms of susceptibility to physical destruction. The threat to be used will be the INTACS threat as furnished by the Government.

2.4.1.1 Quantitative Measure of Effectiveness

Weighted geographic distance of net nodal traffic from the forward edge of the battle area (FEBA).

2.4.1.2 Estimation Procedures

The following steps will be taken to calculate the MOE:

- After the concept has been sized and deployed in conjunction with user requirements data, the busy-hour traffic at each node is segregated into m (m = 1, 2, 3, ... M) categories by message type and precedence.

- Each category m is then assigned a weighting factor W_m (W_m = 1, 2, 3, ... 10) by communications analysts (i.e., a flash operational message may have a value of 10, while a routine administrative message has a value of 2).

- Each node of a network is identified by an integer j, where j = 1, 2, 3, ... N.

- Node by node, the busy-hour traffic is segregated into the m categories to give a message count for node j by category m. The number of messages of the m^{th} category at the j^{th} node is N_{mj}.

- The importance of the j^{th} node is taken by summing the products of N_{mj} by the corresponding weighting factors, W_m:

$$I_j = \sum_{m=1}^{M} N_{mj} W_m$$

where

I_j = importance of the j^{th} node

N_{mj} = number of messages (busy-hour traffic) at the j^{th} node of category m

W_m = weighting factor for category m messages.

- The relative importance of the j^{th} node to the entire system is indicated by:

$$R_j = \frac{I_j}{\Sigma I_j}$$

- The distances (in kilometers) of the j^{th} nodes from the FEBA (as taken from the scenario) are tabulated as D_j.

- Weighted distances of net nodal traffic from FEBA (WDNTF) are computed using the following equation:

$$WDNTF = \sum_{j=1}^{N} \frac{R_j^2}{D_j^2}$$

The higher the WDNTF, the greater the vulnerability of the system from attack.

In addition, answers to the following questions will be used to compare the concepts:

- Considering known enemy detection capabilities, uniqueness, and size or signature of critical nodes in the system, distance from FEBA, physical size, inherent hardware weaknesses, and degree of exposure of equipment and power sources, what is the likelihood of enemy detection?

- In situations with a well-defined FEBA (excluding airmobile operations or a tactical nuclear environment that results in widely dispersed friendly and hostile forces) and considering the known enemy priorities and capabilities, importance of a node, and distance from FEBA, what is the likelihood of an enemy attempt to destroy the node?

- Considering distance from FEBA, physical protection (fortification), proximity to military defense, and the capability of the equipment to withstand damage, what is the capability of averting destruction or damage to a critical node in the event of attack?

- How does mobility affect the vulnerability of the system?

The answers to these questions will be based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.4.1.3 Assumptions and Estimation Conditions

The significance of the quantitative MOE is based on the assumption that an enemy will attack any system element he can locate, provided: 1) he is not gaining useful intelligence from passive intercept and analysis; 2) he is unable to take advantage of manipulative deception techniques; or 3) he us unable to successfully jam the element. It is further assumed that the vulnerability of an element decreases proportionally to the square of its distance from the enemy; however, this measure does not properly apply to the use of satellites as nodes, nor to situations where a well-defined FEBA does not exist.

In all cases, nodes will be located in such a manner that the effective radius of the enemy's largest conventional weapon could not damage or destroy, with a single hit, more than one node.

2.4.2 Aspect: Susceptibility to Direction-Finding

The degree to which unit positions are compromised by a candidate concept is indicated by the EMC/EMV direction-finding scores of the net types. In the direction-finding subtest, the paths between friendly transmitters and enemy intercept receivers are considered and scored on the basis of a minimum signal strength required at the enemy receiver to affect direction-finding, but not necessarily enough to affect clear reception (i.e., this subtest is similar to interceptibility, but different minimum received signal criteria are used).

2.4.2.1 Quantitative Measure of Effectiveness

Weighted average of EMC/EMV analysis direction-finding subtest scores.

2.4.2.2 Estimation Procedures

The EMC/EMV analysis direction-finding output consists of a series of scores by net type. The MOE is a weighted arithmetic mean of these scores on the basis of the number of nets of the net type and a weighted value for the net type determined by communications analysts*:

$$WDF = \frac{\sum_{t=1}^{T} V_t \, N_t \, (DF)_t}{\sum_{t=1}^{T} V_t \, N_t} \qquad (0 \leq WDF \leq 100)$$

where

WDF = weighted average of EMC/EMV analysis direction-finding subtest score

T = number of different discrete net types

t = a discrete net type, t=1, 2, 3, 4, ... T

V_t = value of net type t $(0 \leq V_t \leq 10)$

N_t = number of nets of net type t in the system, $N_t = 1, 2, 3, 4, \ldots$

$(DF)_t$ = direction-finding subscore for net type t.

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* Where applicable, these will be taken from DACE-CMS-E letter of 27 December 1973, Subject: Standards for Weighting Communications and Electronics Nets and Links in Simulated Force Models.

2.4.2.3 Assumptions and Estimation Conditions

None.

2.4.3 Aspect: Interceptibility

The extent to which an enemy can monitor traffic and message flow in a candidate concept is indicated by the EMC/EMV intercept subtest score. The interference prediction model computes compatibilities over paths between victim transmitters and enemy intercept receivers. The lower the interceptibility, the greater the transmission security of the candidate concept.

2.4.3.1 Quantitative Measure of Effectiveness

Weighted average of EMC/EMV analysis intercept subtest scores.

2.4.3.2 Estimation Procedures

The EMC/EMV subtest output will be in the form of a series of scores by net type. The MOE is a weighted arithmetical mean of these scores on the basis of the number of nets of the net type and a weighted value for the net type determined by communications analysts*:

$$WIN = \frac{\sum_{t=1}^{T} V_t\ N_t\ (IN)_t}{\sum_{t=1}^{T} V_t\ N_t} \qquad (0 \leq WIN \leq 100)$$

where

WIN = weighted average of EMC/EMV analysis intercept subtest scores

T = number of different discrete net types

t = a discrete net type, t=1, 2, 3, 4, ... T

V_t = value of net type t ($0 \leq V_t \leq 10$)

N_t = number of nets of net type t in the system, N_t=1, 2, 3, 4, ...

$(IN)_t$ = intercept score for net type t.

2.4.3.3 Assumptions and Estimation Conditions

None.

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* Where applicable, these will be taken from DACE-CMS-E letter of 27 December 1973, Subject: Standards for Weighting Communications and Electronics Nets and Links in Simulated Force Models.

2.5 AREA: SURVIVABILITY

Survivability is defined as the capability of a communications system to degrade gracefully in mission performance after having suffered destructive physical or electronic attack. Survivability includes the following aspects:

- Impact of destruction of communications system nodes
- Impact of jamming.

2.5.1 Aspect: Impact of Destruction of Communications System Nodes

The concepts will be evaluated according to their ability to provide continuity and quality of service after the total or partial destruction of one or more nodes in the system. This will include consideration of backup equipment, alternate routing, alternate transmission modes, alternate power sources, and the option of re-engineering the system. Entire nodes, selected functions at a node, and power sources will be analyzed in terms of the impact of their destruction on the system. The study will address the loss of subscribers, recovery time, and degradation of GOS due to such destruction.

2.5.1.1 Quantitative Measure of Effectiveness

- Number of nodes that must be destroyed before GOS is reduced to certain specific levels;
- Subscriber loss resulting from nodal destruction.

2.5.1.2 Estimation Procedures

GOS will be measured by SIMCE at the system busy hour in the scenario. Based on traffic volume at the busy hour, the node that handles the most traffic will be identified and considered destroyed. Subscriber loss due to the destroyed node will be estimated by communications analysts. GOS will be recomputed by SIMCE, to indicate the results of the destruction of the node. The process of identifying and destroying the busiest node and then measuring the impact of that destruction is reiterated until, in the judgement of the communications analysts, the communications system fails to provide minimal acceptable service. Specific levels of degradation (in terms of GOS) will be highlighted and the degree of destruction (number of nodes destroyed) resulting in this degradation will be indicated for each concept.

The above procedure will be used to calculate the quantitative MOEs. Additionally, answers to the following questions will be used to compare the concepts:

- What capability exists to provide backup equipment in response to total or partial destruction at a node?
- What capability exists for alternate routing in response to total or partial destruction at a node?
- What capability exists for using alternate transmission modes in response to total or partial destruction at a node?
- What capability exists for using alternate power sources in response to destruction of primary power sources of equipment at a node?
- What capability exists for re-engineering the nodal network in response to total or partial destruction at a node?
- How does the organizational structure of TCCF affect its ability to coordinate the restoration of the communications system after total or partial destruction at a node?
- What is the outage time due to total or partial destruction at a node?

The answers to these questions will be subjective and based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.5.1.3 Assumptions and Estimation Conditions

In a network simulation model, satellites will be considered nodes that might be destroyed; the impact of this will be evaluated by the estimation procedure outlined above.

2.5.2 Aspect: Impact of Jamming

The degree to which enemy jamming disrupts operation of a candidate concept is indicated by the EMC/EMV jamming vulnerability score. The basis of the score is the reduction in compatibility score experienced by victim receiver(s) (e.g., satellite, net radio, MARTS, etc.) as a result of enemy jamming. This reduction in compatibility will reflect the success or failure of the enemy ECM effort.

2.5.2.1 Quantitative Measure of Effectiveness

Weighted average of EMC/EMV analysis jamming vulnerability subtest scores.

2.5.2.2 Estimation Procedures

The EMC/EMV analysis jamming vulnerability output consists of a series of scores by net type. The MOE is a weighted arithmetic mean of these scores on the basis of the number of nets of the net type and a weighted value for the net type determined by communications analysts*:

$$WJM = \frac{\sum_{t=1}^{T} V_t N_t (JM)_t}{\sum_{t=1}^{T} V_t N_t} \qquad (0 \le WJM \le 100)$$

where

WJM = weighted average of EMC/EMV analysis jamming vulnerability subtest score

T = number of different discrete net types

t = a discrete net type, $t=1, 2, 3, 4, \ldots T$

V_t = value of net type t $(0 \le V_t \le 10)$

N_t = number of net type t in the system ($N_t = 1, 2, 3, 4, \ldots$)

$(JM)_t$ = jamming subscore of net type t.

2.5.2.3 Assumptions and Estimation Conditions

The jamming model in CASE will not be used.

2.6 AREA: FLEXIBILITY

Flexibility is defined as the capability of the system to expand, contract, and/or reorganize to satisfy a variety of communications requirements. Flexibility includes the following aspects:

- Ability to function in various operational environments
- Ability to adapt to changing force structure
- Ability to meet the commander's change in mission

* Where applicable, these will be taken from DACE-CMS-E letter of 27 December 1973, Subject: Standards for Weighting Communications and Electronics Nets and Links in Simulated Force Models.

- Ability to adapt to various ratios of traffic types
- Ability to add subscribers
- System modularity
- Downtime due to CP displacement
- Ability to operate in dispersed or concentrated deployments
- Hardware modularity.

2.6.1 Aspect: Ability to Function in Various Operational Environments

The concepts will be evaluated according to their ability to function in various types of warfare (specifically, tactical nuclear and tactical non-nuclear) and in various terrains. This ability to function is influenced by vulnerability, survivability, maintainability, logistical support requirements, mobility, transportability, RF spectrum requirements, and quality of service.

2.6.1.1 Quantitative Measure of Effectiveness

Not applicable.

2.6.1.2 Estimation Procedures

Answers to the following questions form the basis for concept comparison:

- How does susceptibility (to weather, ECM, ground or air attack) differ in various operational environments?
- How does the impact of electronic jamming or physical destruction differ in various operational environments?
- How do the maintenance/logistical requirements (for corrective maintenance, software updates, and power requirements) differ in various operational environments?
- How does mobility (in terms of setup/teardown time and the ability to communicate while moving) differ in various operational environments?
- How do the number and type of vehicles required to support the communications system differ in various operational environments?

- How do the RF spectrum requirements differ in various operational environments?

- How do GOS and information intelligibility differ in various operational environments?

The answers to these questions will be based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.6.1.3 Assumptions and Estimation Conditions

The concepts will not be compared for changes in security due to the various operational environments.

2.6.2 Aspect: Ability to Adapt to Changing Force Structure

The concepts will be evaluated according to their ability to accommodate additional units. Specifically, the Brigade will be examined with an additional battalion; the Division with an additional brigade; the Corps with an additional brigade or division; and the Theater Army with an additional division or corps, or with such special forces as air defense, field artillery, and Army Tactical Data Systems (ARTADS). The ability to adapt to changing force structure will be influenced by maintenance/logistical requirements, transportability, RF spectrum requirements, and quality of service.

2.6.2.1 Quantitative Measure of Effectiveness

Not applicable.

2.6.2.2 Estimation Procedures

The following questions form the basis for concept comparison:

- How do the requirements for software updates differ when additional units are deployed in the force structure?

- How does the increased burden of meeting power requirements (generators, batteries, etc.) differ when additional units are deployed in the force structure?

- How does the increased burden of meeting supply and transportation requirements differ when additional units are deployed in the force structure?

- How do RF spectrum requirements (frequency assignment to minimize friendly interference) differ when additional units are deployed in the force structure?

- How does the quality of service (in terms of GOS and information intelligibility) differ when additional units are deployed in the force structure?

The answers to these questions will be subjective and based on a qualitative analysis of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.6.2.3 Assumptions and Estimation Conditions

The concepts will not be compared for changes in security due to changing force structure.

2.6.3 Aspect: Ability to Meet Commander's Change in Mission

The concepts will be evaluated according to their ability to satisfy communications requirements imposed by a change in the commander's mission from/to each of the following: defense, attack, withdrawal, or reinforcement. Specifically, at the echelons of Brigade and Division, the effects of a change from each mission to each of the other three missions will be examined. The ability to meet the commander's change in mission will be influenced by vulnerability, survivability, maintainability, logistical support requirements, mobility, transportability, RF spectrum requirements, and quality of service.

2.6.3.1 Quantitative Measure of Effectiveness

Not applicable.

2.6.3.2 Estimation Procedures

Answers to the following questions form the basis for concept comparison:

- How does susceptibility (to weather, ECM, ground or air attack) differ with the mission?

- How does the impact of electronic jamming or physical destruction differ with the mission?

- How do the maintenance/logistical requirements (for corrective maintenance, software updates, and power requirements) differ with the mission?

- How does mobility (in terms of setup/teardown time and the ability to communicate while moving) differ in changing from one mission to another?

- How do the number and type of vehicles required to support the communications system differ with the mission?

- How do GOS and information intelligibility differ with a change in mission?

The answers to the questions will be subjective and based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.6.3.3 Assumptions and Estimation Conditions

The concepts will not be compared for changes in security due to the commander's change in mission.

2.6.4 Aspect: Ability to Adapt to Various Ratios of Traffic Types

The concepts will be evaluated according to their ability to handle changing ratios of traffic types: data, teletype, facsimile, and voice. Specifically, the percentage of data will be increased at the expense of the percentage of voice.

2.6.4.1 Quantitative Measure of Effectiveness

Percentage of GOS degradation due to increasing ratio of data/voice traffic types.

2.6.4.2 Estimation Procedures

The actual measure of the ability to adapt to various ratios of traffic types will be the percentage of change in grade of service due to increasing the percentage of data traffic. If a saturation point exists, it will be identified. The system busy-hour traffic (from the scenario) will be identified by traffic type and converted to a common denominator, and "current" percentage levels will be established. The percentage of data traffic will be increased at the expense of voice traffic and the resultant GOS, computed by SIMCE, will be plotted accordingly.

Other implications of data transmission will be indicated by the effect of the data rate and bandwidth requirements for data transmission on information intelligibility and susceptibility to jamming of such systems as TOS and TACFIRE. The determination of these requirements will be subjective, and will be based on a qualitative evaluation by communications analysts. This will be in the form of a qualitative MOE.

2.6.4.3 Assumptions and Estimation Conditions

Messenger service is not included in the computation of percentages of traffic types. As the ratio of data-to-voice traffic increases, traffic volume will increase. The extent of the increase will be estimated

by the communications analysts and used as a factor in evaluating GOS. The differences between all digital/hybrid/analog systems will be considered.

2.6.5 Aspect: Ability to Add Subscribers

The concepts will be evaluated at the echelons of Brigade and Division according to their ability to accommodate additional subscribers (smaller in number than a company). Specifically, the RF spectrum and logistical support requirements will be investigated.

2.6.5.1 Quantitative Measure of Effectiveness

Not applicable.

2.6.5.2 Estimation Procedures

Answers to the following questions form the basis for concept comparison:

- When additional subscribers enter the area, how do the RF spectrum requirements change?
- When additional subscribers enter the area, how do the logistical support requirements change?

The answers to these questions will be based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.6.5.3 Assumptions and Estimation Conditions

The concepts will not be compared for changes in security due to additional subscribers.

2.6.6 Aspect: System Modularity (ability to fragment the system without degradation)

The concepts will be evaluated at the echelons of Brigade, Division, Corps, and Theater Army according to their ability to provide continuity of service to the main body and, at the same time, to satisfy the communications requirements of a unit on a special mission and physically separated from the main body. The ability to fragment the system will be influenced by quality of service and RF spectrum requirements.

2.6.6.1 Quantitative Measure of Effectiveness

Not applicable.

2.6.6.2 Estimation Procedures

Answers to the following questions form the basis for concept comparison:

- How do GOS and information intelligibility change when a unit is fragmented from the main body but is still supported by it?
- What GOS and information intelligibility can this fragmented unit expect?
- How do RF spectrum requirements change?

The answers to these questions will be subjective and based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.6.6.3 Assumptions and Estimation Conditions

The concepts will not be compared for changes in security due to system fragmentation.

2.6.7 Aspect: Downtime Due to CP Displacement

The concepts will be evaluated according to their ability to reconstitute the communications system after CP displacement. This ability will be indicated by the total time required to accomplish CP displacement and by the degree of communications loss due to this displacement.

2.6.7.1 Quantitative Measure of Effectiveness

Down minutes due to CP displacement.

2.6.7.2 Estimation Procedures

Subscribers that lose communications capability due to CP displacement will be identified. A weighting factor will be applied to those subscribers indicating their relative importance in terms of rank and position; i.e.,

$$\text{Total Down Minutes} = \sum_{s=1}^{S} W_s T_s$$

where

S = total number of subscribers suffering loss of communications capability due to CP displacement

s = discrete subscriber, $s=1, 2, 3, 4, \ldots S$

W_s = weighting factor for subscriber s

T_s = downtime in minutes for subscriber s.

2.6.7.3 Assumptions and Estimation Conditions

The downtime in minutes for each subscriber will be estimated by communications analysts. Backup capability will be considered, and total down minutes will be calculated in two ways:

- By ignoring backup capability
- By discounting down minutes for any subscriber with a a backup capability.

It is assumed that the force can tolerate downtime for some subscribers with no loss of combat effectiveness.

2.6.8 Aspect: Ability to Operate in Dispersed or Concentrated Deployments

The concepts will be evaluated according to their ability to function in either dispersed or concentrated deployments. The ability to function will be influenced by vulnerability, survivability, maintainability, logistical support requirements, mobility, transportability, RF spectrum requirements, and quality of service.

2.6.8.1 Quantitative Measure of Effectiveness

Not applicable.

2.6.8.2 Estimation Procedures

Answers to the following questions will form the basis for concept comparison:

- How does susceptibility (to weather, ECM, ground or air attack) differ in dispersed or concentrated deployments?
- How does the impact of electronic jamming or physical destruction differ in dispersed or concentrated deployments?
- How do the maintenance/logistical requirements (for corrective maintenance, software updates, and power requirements) differ in dispersed or concentrated deployments?
- How does mobility (in terms of setup/teardown time and the ability to communicate while moving) differ in dispersed or concentrated deployments?
- How do the number and type of vehicles required to support the communications system differ in dispersed or concentrated deployments?
- How do RF spectrum requirements differ in various operational environments?

- How do GOS and information intelligibility differ in various operational environments?

The answers to these questions will be subjective and based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.6.8.3 Assumptions and Estimation Conditions

None.

2.6.9 Aspect: Hardware Modularity

The concepts will be evaluated according to the increase in system performance that results from hardware modularity. This increase in system performance is influenced by changes in mobility, transportability, logistical support requirements, security, standardization, and maintainability.

2.6.9.1 Quantitative Measure of Effectiveness

Not applicable.

2.6.9.2 Estimation Procedures

Answers to the following questions will form the basis for concept comparison:

- How does hardware modularity affect setup/teardown time and the ability to communicate during movement?

- How does hardware modularity affect portability?

- How does hardware modularity affect logistical support requirements?

- How does hardware modularity affect the ability to convert from nonsecure to secure equipment?

- How does hardware modularity affect the standardization of CE equipment?

- How does hardware modularity affect maintainability?

The answers to these questions will be based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.6.9.3 Assumptions and Estimation Conditions

The system designers will provide information on modularity for any hardware currently in R&D.

2.7 AREA: RELIABILITY

Reliability is defined as the probability that the communications system perform its mission adequately for the time intended under the operation conditions expected to be encountered. Since traffic blockage is measured separately under GOS, this area will concern equipment performance and not equipment capacity. Reliability includes the aspect of system availability.

2.7.1 Aspect: System Availability

The concepts will be evaluated by calculating the probability that equipment failure will not degrade system performance. This involves measuring equipment reliability and identifying routing capability.

2.7.1.1 Quantitative Measure of Effectiveness

Percent system availability.

2.7.1.2 Estimation Procedures

The system design effort in Task V will provide TOEs for each unit within an echelon. For the equipment specified in the TOEs, mean time between failure (MTBF), mean time to repair (MTTR), and the NORM rate will be calculated as indicated in Subsection 2.12.2. Operational availability, A, for each discrete type of equipment will be computed by the following equation:

$$A = \frac{a_i}{1 - a_i} \text{ NORM}$$

where a_i is inherent availability and equal to

$$\frac{\text{MTBF}}{\text{MTBF + MTTR}}$$

If backup equipment exists on-site, or if an alternate routing capability exists, the equipment is considered to be in parallel operation at that point; otherwise, the equipment is considered to be in series operation. Figure A-1 demonstrates a path of equipment in series; Figure A-2 demonstrates equipment in parallel; and Figure A-3 demonstrates a series of parallel configurations of equipment.

Total availability with equipment in series, A_{tot}, is a product relationship of the individual (operational) availabilities:

$$A_{tot} = \prod_i A_i$$

where A_i = the availability of the i^{th} equipment in series. The availability along the path of Figure A-1 is computed as:

$$A(\text{path}) = A(X_1) \cdot A(X_2) \cdot A(X_3)$$

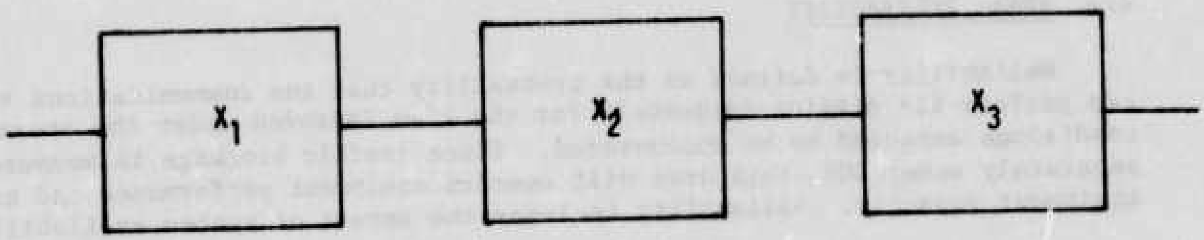

FIGURE A-1 Equipment in Series

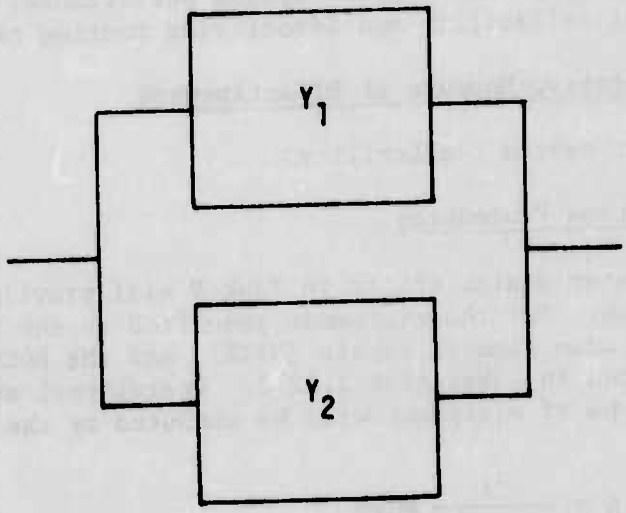

FIGURE A-2 Equipment in Parallel

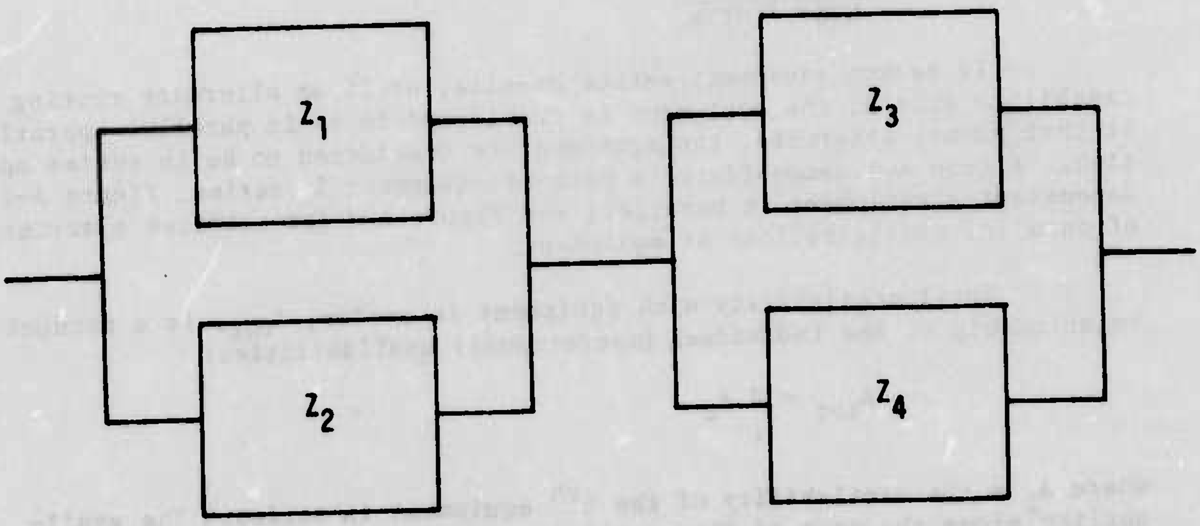

FIGURE A-3 Series of Equipment in Parallel

That is, if

$$A(X_1) = A(X_2) = A(X_3) = 0.9$$

then

$$A(\text{path}) = 0.729.$$

Total availability with equipment in parallel is calculated differently, since failure occurs only when all equipment in parallel has failed simultaneously. Thus,

$$A_{tot} = 1 - \prod_j (1 - A_j)$$

where A_j represents the availability of the j^{th} equipment in parallel. The availability along the path of Figure A-2 is computed as:

$$A(\text{path}) = 1 - (1 - A(Y_1)) \cdot (1 - A(Y_2))$$

That is, if

$$A(Y_1) = A(Y_2) = 0.9$$

then

$$A(\text{path}) = 1 - 0.01 = 0.99.$$

Total availability of a system containing parallel configurations can be expressed as:

$$A_{tot} = \prod_i A_i$$

where A_i represents the availability of the i^{th} equipment/configuration in series. Thus,

$$A_i = 1 - \prod_p (1 - A_{ip})$$

where A_{ip} represents the availability of the p^{th} equipment in configuration of the i^{th} position in series, where:

$$p > 1 \text{ if parallel configuration exists}$$

$$p = 1 \text{ otherwise.}$$

The availability along the path of Figure A-3 is computed as:

$$A(\text{path}) = (1 - (1 - A(Z_1)) \cdot (1 - A(Z_2)))$$
$$\cdot (1 - (1 - A(Z_3)) \cdot (1 - A(Z_4)))$$

That is, if

$$A(Z_1) = A(Z_2) = A(Z_3) = A(Z_4) = 0.9$$

then

$$A(\text{path}) = (0.99) \cdot (0.99) = 0.9801.$$

The concepts under consideration contain parallel configurations in series, and therefore will be evaluated by the above procedure. Critical paths of equipment, based on their importance to mission performance, will be identified by communications analysts. Availability for these paths will be calculated, and a mean and variance of these availabilities will comprise the actual MOE.

2.7.1.3 Assumptions and Estimation Conditions

None.

2.8 AREA: LOGISTICAL SUPPORT

Logistical support is defined as the provision of adequate materiel and services to a military force to assure successful accomplishment of assigned missions. For the communications system, logistical support includes the following aspects:

- Ease of providing required parts support
- Power requirements.

2.8.1 Aspect: Ease of Providing Required Parts Support

The concepts will be evaluated according to the size and weight of equipment in the inventory required to support the communications system. Additionally, the NORS rates of critical equipment will be indicated. Stockage levels will be examined, and parts/maintenance support centers will be evaluated with respect to their proximity to using units.

2.8.1.1 Quantitative Measure of Effectiveness

- NORS rate for critical components of the system;
- Cubic feet of storage to maintain the necessary spare parts inventory in support of the communications system.

2.8.1.2 Estimation Procedures

The system design effort in Task V will provide TOEs for each unit within an echelon. These TOEs indicate quantities of types of equipment required. Spare parts required for preventive and corrective maintenance of equipment will be identified (including throw-away parts), and the storage volume (in cubic feet) required for spare parts will be calculated.

The NORS rate for critical components of the system will be calculated from empirical data provided by the Army Logistics Management Center (ALMC) at Fort Lee.

Additionally, answers to the following questions will be used to compare the concepts:

- What stockage levels are required to support the system?
- How do the locations of parts/maintenance support centers affect the ability to support the using units?

The answers to these questions will be subjective and based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.8.1.3 Assumptions and Estimation Conditions

For all equipment in the current inventory, spare parts requirements can be identified from technical manuals. For equipment currently in R&D, the system designers will provide this information.

Storage requirements for spare parts will also be provided by system designers. Empirical data necessary for the calculation of NORS rates will be GFI.

Consummables needed to support manpower requirements, such as food and clothing, will not be considered.

2.8.2 Aspect: Power Requirements (generators, batteries, etc.)

The concepts will be evaluated according to power requirements. The different sources of power will be identified, and the total requirements for each type of source will be determined.

2.8.2.1 Quantitative Measure of Effectiveness

Total power, by source type, required to support the communications system.

2.8.2.2 Estimation Procedures

The system design effort in Task V will provide TOEs for each unit within an echelon. These TOEs indicate quantities of types of equipment required for each alternative. For this equipment, both primary and backup power requirements will be considered and totaled by source type.

2.8.2.3 Assumptions and Estimation Conditions

Gasoline for transport vehicles will be excluded. For all equipment in the current inventory, power requirements are indicated in technical manuals. For equipment currently in R&D, the system designers will provide this information.

2.9 AREA: SECURITY

Communications security is the protection that results from all measures designed: 1) to deny unauthorized persons information of value that might be derived from the possession and study of telecommunications, or 2) to mislead unauthorized persons in their interpretation of the results of such possession and study. Communications security includes: 1) cryptosecurity; 2) transmission security; 3) emission security; and 4) physical security of communications security material and information.

Cryptosecurity is the component of communications security that results from the provision of technically sound cryptosystems and their proper use.

Transmission security is the component of communications security that results from all measures designed to protect transmission from interception and exploitation by means other than cryptoanalysis.

Emission security is the component of communications security that results from all measures taken to deny unauthorized persons information of value that might be derived from intercept and analysis of compromising emanations from cryptoequipment and telecommunications systems.

Physical security is the component of communications security that results from all physical measures necessary to safeguard classified equipment, material, and documents from access thereto or observations thereof by unauthorized persons.

For the purpose of this study, communications security includes the following aspects:

- Ability to provide increased secure communications;
- Limitations imposed through increased security;

- Ability to accommodate increasing ratios of secure to nonsecure subscribers;
- Ability to satisfy interface security requirements;
- Ability to restore secure communications after compromise;
- Degree of security.

Interceptibility is an aspect previously covered under security; however, it is addressed within the area of vulnerability.

2.9.1 Aspect: Ability to Provide Increased Secure Communications

The concepts will be evaluated according to their ability to provide secure communications by transmission mode to those who need it. The following modes will be considered: voice (wideband and narrowband, analog and digital), data, teletype, and facsimile. Evaluation will also include wire and cable/RF tradeoffs, TCCF functions, RF spectrum requirements, and terminal equipment.

2.9.1.1 Quantitative Measure of Effectiveness

Not applicable.

2.9.1.2 Estimation Procedures

Answers to the following questions will form the basis for concept comparison:

- When considering wire and cable/RF tradeoffs, what are the effects of the differences in setup/teardown time, support requirements (manpower and logistics commitments), and degree of security (link versus end-to-end), and how do these differences relate to each concept?
- How does the organizational structure of TCCF affect its ability to perform the functions of secure circuit monitoring, reporting, restoring, and patching?
- What are the effects of the increased RF spectrum and terminal equipment requirements caused by increasing security for each mode of transmission?

The answers to these questions will be based on a qualitative evaluation of each of the concepts performed by the communications analysts. These answers will be in the form of a qualitative MOE.

2.9.1.3 Assumptions and Estimation Conditions

The following assumptions and estimation conditions are made:

- Trained operators will be available;
- Cryptosystems to be employed will be secure from exploitation;
- The number of secure terminal subscribers will not vary among the concepts.

2.9.2 Aspect: Limitations Imposed Through Increased Security

The concepts will be evaluated according to the degree of reduction in system performance caused by increased demands on the system when security is provided. These limitations are caused by increased space and weight, increased logistical support requirements, increased RF spectrum requirements, increased setup/teardown time, the mix of secure/nonsecure subscribers at a switch, and lower noise tolerance necessary for secure transmission.

2.9.2.1 Quantitative Measure of Effectiveness

Not applicable.

2.9.2.2 Estimation Procedures

Answers to the following questions will form the basis for concept comparison:

- How do the increased equipment requirements for security increase space and weight considerations (system/user)?
- What is the increase in manpower, logistical, and crypto material requirements resulting from increased transmission security?
- What is the increase in RF spectrum requirements resulting from increased transmission security?
- What is the increase in setup/teardown time resulting from increased transmission security?
- Assuming that a mix of secure/nonsecure subscribers is inevitable, what limitations are imposed upon the switch?
- What is the effect of the lower noise tolerance necessary for transmission security?

The answers to these questions will be based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.9.2.3 Assumptions and Estimation Conditions

COMSEC equipment will be in the hands of trained operators.

2.9.3 Aspect: Ability to Accommodate Increasing Ratios of Secure to Nonsecure Subscribers

The concepts will be evaluated according to their ability to accommodate a system-wide increase in the percentage of secure subscribers, with the goal to eventually achieve 100 percent security. Factors that influence this ability include RF spectrum requirements, logistical support requirements, and transportability.

2.9.3.1 Quantitative Measure of Effectiveness

Not applicable.

2.9.3.2 Estimation Procedures

Answers to the following questions will form the basis for concept comparison:

- What limitations to increasing the number of secure subscribers are imposed by RF spectrum requirements?
- What limitations to increasing the number of secure subscribers are imposed by an inability to meet the increased manpower, logistical, and crypto material requirements?
- What limitations to increasing the number of secure subscribers are imposed by space or weight considerations?
- What limitations to increasing the number of secure subscribers are imposed by situations of high risk of compromise or capture (proximity to enemy, overflight)?
- What limitations to increasing the number of secure subscribers are imposed by the mix of secure/nonsecure subscribers at a switch?
- What limitations to increasing the number of secure subscribers are imposed by adding subscribers (units or individuals)?

The answers to these questions will be based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.9.3.3 Assumptions and Estimation Conditions

Cost implications will be addressed during sensitivity analysis and will not be considered during concept evaluation for this aspect.

2.9.4 Aspect: Ability to Satisfy Interface Security Requirements

The concepts will be evaluated according to their ability to satisfy interface security requirements on the following levels: allied, joint, interservice, and DCS, both laterally and vertically. Consideration will be given to cryptoequipment interoperability and compatibility of procedures.

2.9.4.1 Quantitative Measure of Effectiveness

Not applicable.

2.9.4.2 Estimation Procedures

Answers to the following questions will form the basis for concept comparison:

- What is the status of cryptoequipment interoperability, and how does this affect security interface capability?
- What is the status of crypto procedures compatibility, and how does this affect security interface capability?

The answers to these questions will be based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.9.4.3 Assumptions and Estimation Conditions

None.

2.9.5 Aspect: Ability to Restore Security After Compromise

The concepts will be evaluated according to their ability to restore security after compromise of hardware or crypto material. Compromise includes capture or successful cryptoanalysis by the enemy. In the event of compromise, it is the responsibility of TCCF and cryptosecurity personnel to coordinate the restoration of security.

2.9.5.1 Quantitative Measure of Effectiveness

Not applicable.

2.9.5.2 Estimation Procedures

Answers to the following questions will form the basis for concept comparison:

- What is the impact on security of hardware compromise?
- What replacement capability exists in the event of hardware compromise?

- What is the impact on security of compromise of crypto material?
- What are the capabilities of the system in redistributing (by physical or electronic means) crypto material in the event of compromise?
- How do crypto logistics procedures affect the ability to rapidly restore security after compromise?
- What influence does the organizational structure of TCCF have on the ability to react to compromise?

The answers to these questions will be based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.9.5.3 Assumptions and Estimation Conditions

The following assumptions and estimation conditions are made:

- COMSEC equipment will be in the hands of trained operators;
- No effort will be made to evaluate the ability to detect the compromise situation (for the purposes of this study, it is assumed that the compromise situation is known to have occurred);
- Circuit restoration will not be evaluated as a part of this aspect.

In that some system features relate to more than one of the above items, the possibility of double-weighting exists and will be addressed during the concept evaluations for this aspect.

2.9.6 Aspect: Degree of Security

The concepts will be evaluated according to the degree of security that is provided. Specifically, end-to-end security and link security will be addressed.

2.9.6.1 Quantitative Measure of Effectiveness

- Number of subscribers provided with end-to-end security.

Two of the original 63 quantitative MOEs have since been dropped (when the number of MOEs was reduced to 60). The following MOEs have been deleted:

- Number of subscribers not provided with end-to-end security who are provided with link security;
- Percentage of subscribers not provided with end-to-end security who can be upgraded to end-to-end security with a modular addition to their equipment.

2.9.6.2 Estimation Procedures

The system design effort in Task V will provide TOEs for each unit within an echelon. From these TOEs, the equipments that provide end-to-end security and link security will be identified. This will be used to determine the number of subscribers in the organization provided with end-to-end security.

2.9.6.3 Assumptions and Estimation Conditions

It is recognized that a commander can, on the basis of physical security, declare that an area has end-to-end security. This situation will be considered in estimating the number of subscribers with end-to-end security.

2.10 AREA: OPERABILITY

Operability is defined as the ease of using the communications system so that it adequately serves the needs of the user. Operability includes the following aspects:

- Degree of difficulty in system operation
- Service features.

2.10.1 Aspect: Degree of Difficulty in System Operation

The concepts will be evaluated according to their directory requirements, call setup procedures, and MOS requirements for system operation.

2.10.1.1 Quantitative Measure of Effectiveness

- Number of personnel, by MOS, required to operate the communications system.

Two of the original 63 MOEs have since been replaced by a qualitative MOE on directory requirements. The MOEs that were deleted are as follows:

- Number of listings required in the directory;
- Number of users that require the directory.

2.10.1.2 Estimation Procedures

The system design effort in Task V will provide manpower requirements, by MOS, for operating and maintaining the equipment. The number of personnel required for operations will be totaled by MOS.

Answers to the following questions will form the basis for the qualitative comparison of the concepts:

- Can directory changes be kept current?
- How does a unit move affect directory requirements?
- What is the degree of difficulty/complexity in the call setup procedure?
- To what degree does the calling party need to know the actual location of the party being called?

The answers to these questions will be based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of two qualitative MOEs:

- Measurement of the ease of maintaining a current directory;
- Measurement of the ease of placing a telephone call.

2.10.1.3 Assumptions and Estimation Conditions

The physical characteristics of the equipment are such that the ease of operating actual equipment does not significantly differ among the concepts.

2.10.2 Aspect: Service Features

Service features are those features that increase system effectiveness by providing capabilities not essential but which are expedient and convenient. A system either has the capability or it does not.

2.10.2.1 Quantitative Measure of Effectiveness

Not applicable.

2.10.2.2 Estimation Procedures

Answers to the following questions form the basis for concept comparison:

- Does the concept offer call reinitiate?
- Does the concept offer command override?
- Does the concept offer prearranged conference calls (one number gets all conferees)?

- Does the concept offer adequate manual backup?
- Does the concept offer callup conference calls?
- Does the concept offer positive ringback?
- Does the concept offer line grouping?
- Does the concept offer automatic signaling?
- Does the concept offer automatic routing?
- Does the concept offer compressed/abbreviated dialing?
- Does the concept offer call transfer?

2.10.2.3 Assumptions and Estimation Conditions

The answers to these questions will be provided by communications analysts.

2.11 AREA: STANDARDIZATION

Standardization is defined as the ability of a communications system design to use common, compatible, or interchangeable equipment and supplies. Standardization includes the aspect of multiplicity of CE equipment.

2.11.1 Aspect: Multiplicity of CE Equipment

The degree of standardization of CE equipment will be determined for each concept. Specifically, the number of categories or families of CE equipment will be computed.

2.11.1.1 Quantitative Measure of Effectiveness

Number of categories of CE equipment required by each concept.

2.11.1.2 Estimation Procedures

The system design effort in Task V will provide TOEs for each unit within an echelon. The TOEs indicate quantities and types of equipment to be employed. The next three steps are as follows:

- Determine the families into which the equipment is to be categorized;
- Place each piece of equipment in the appropriate family of equipment;
- Enumerate the families of equipment.

2.11.1.3 Assumptions and Estimation Conditions

Categorization by families for all equipment (including those currently in R&D) will be performed by the system designers.

2.12 AREA: MAINTAINABILITY

Maintainability is defined as the ease with which the necessary preventive, corrective, and software maintenance can be provided for the communications system. Maintainability includes the following aspects:

- Ease of providing preventive maintenance
- Ease of providing corrective maintenance
- Ease of updating software.

2.12.1 Aspect: Ease of Providing Preventive Maintenance

The concepts will be evaluated according to the amount of scheduled maintenance (manhours by MOS) required for the system and the ease of providing that maintenance. This ease will be determined by considering the physical location of the equipment, test equipment, and spare parts required for maintenance, and the downtime that must be scheduled for the maintenance.

2.12.1.1 Quantitative Measure of Effectiveness

- Total manhours, by MOS, to provide preventive maintenance for the system;
- Percentage of total manhours of preventive maintenance that can be performed without the need for additional test equipment;
- Cubic feet of storage necessary for spare parts required in the inventory for preventive maintenance.

2.12.1.2 Estimation Procedures

The system design effort in Task V will provide TOEs for each unit within an echelon. These TOEs indicate quantities of types of equipment required for each alternative. For the equipment of each alternative, the MOS required for maintenance and the required scheduled maintenance will be identified. From this information, the total manhours, by MOS, to provide preventive maintenance to the system will be calculated.

By identifying the scheduled preventive maintenance that can be accomplished without the use of additional equipment, a percentage of such maintenance in terms of manhour requirements can be calculated.

The system design effort will provide information that indicates the storage volume required for spare parts needed in the inventory for preventive maintenance.

Answers to the following questions will form the basis for the qualitative comparison of the concepts:

- To what degree does the physical location (remoteness) of deployed equipment result in an additional burden in providing scheduled maintenance?

- How does the required downtime that must be scheduled for maintenance affect system performance?

The answers to these questions will be based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.12.1.3 Assumptions and Estimation Conditions

For all equipment in the current inventory, associated MOSs, scheduled preventive maintenance, and spare parts requirements can be identified from technical manuals. For equipment currently in R&D, the system designers will provide this information. Storage requirements for spare parts will also be provided by system designers.

2.12.2 Aspect: Ease of Providing Corrective Maintenance

The concepts will be evaluated according to the amount of corrective maintenance (manhours by MOS) required for the system and the ease of providing that maintenance. The amount of corrective maintenance required will be determined by the MTBF and the MTTR for the equipment. The ease of providing the maintenance will be determined by considering the physical location of the equipment in relation to the test equipment, spare parts, and manpower (by MOS) that is required for the maintenance.

2.12.2.1 Quantitative Measure of Effectiveness

- Estimated total manhours, by MOS, required to provide corrective maintenance for the system;

- Percentage of estimated total manhours of corrective maintenance that can be performed without the need for additional test equipment;

- Cubic feet of storage necessary for spare parts required in the current inventory for corrective maintenance;

- NORM rate for the components of the system.

2.12.2.2 Estimation Procedures

The system design effort in Task V will provide TOEs for each unit within an echelon. These TOEs indicate quantities of types of equipment required for each alternative. For each component of each alternative, the MOS required for maintenance will be specified. On the basis of engineering experience or accumulated data on past failures and repair times,

the MTBF and MTTR will be determined for the equipment. Within the calculation of MTTR will be the estimated manhours required to make the repair. From this information, the total manhours (by MOS) to provide corrective maintenance to the system will be estimated.

The above information will involve itemizing specific expected repair work and the time required to accomplish these specific repairs. By categorizing these repair needs into those that require and those that do not require additional test equipment, a percentage is obtained that indicates the estimated total manhours of corrective maintenance that can be performed without additional test equipment.

The system design effort will provide information on the storage volume required for spare parts needed in the inventory for corrective maintenance.

The NORM rate will be calculated from empirical data provided by the Army Logistics Management Center at Fort Lee.

Answers to the following questions will form the basis for the qualitative comparison of the concepts:

- What is the capability of TCCF in detecting and identifying equipment failure?

- To what degree does the physical location (remoteness) of deployed equipment result in an additional burden in providing corrective maintenance?

The answers to these questions will be based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.12.2.3 Assumptions and Estimation Conditions

For all equipment in the current inventory, MOS and spare parts requirements will be identified from technical manuals. For equipment currently in R&D, the system designers will provide this information.

Storage requirements for spare parts will also be provided by system designers. Empirical data necessary for the calculation of NORM rates will be GFI.

2.12.3 Aspect: Ease of Software Updates

The concepts will be evaluated according to the estimated time, in manhours by skill level, to perform software modifications either on a continual basis or as required by any special situation. The ease of providing these updates in the field is further indicated by the extra personnel required (in addition to on-site operations and maintenance personnel)

and by the extra software/hardware aids needed for update tests and debugging procedures.

2.12.3.1 Quantitative Measure of Effectiveness

- Manhours per language (skill level) for continual needs;
- Manhours per language for each special situation that dictates software update.

2.12.3.2 Estimation Procedures

Communications analysts, in conjunction with system designers, will perform the following steps:

- Identify system software that might require modification in a changing environment;
- Determine situations that dictate software modification;
- Identify situations that can be considered continual;
- Indicate the language and estimate the extend of modification in terms of manhours required for individuals proficient in that language;
- Summarize manhours per language (skill level) for continual needs and also for each special situation that dictates software modification.

In addition, answers to the following questions will be used to compare the concepts:

- In addition to on-site operations and maintenance personnel, what personnel are required to perform software updates in the field?
- What extra software/hardware aids are needed for update tests and debugging procedures?

The answers to these questions will be based on a qualitative evaluation of each of the concepts performed by communications analysts. These answers will be in the form of a qualitative MOE.

2.12.3.3 Assumptions and Estimation Conditions

None.

2.13 AREA: RF SPECTRUM REQUIREMENTS

Two factors are included in the evaluation of spectrum requirements for each concept: the amount of RF bandwidth to support the concept, and the flexibility of necessary frequency allocations. RF spectrum requirements include the following aspects:

- RF bandwidth requirements
- Flexibility of frequency allocation.

2.13.1 Aspect: RF Bandwidth Requirements

This aspect examines the amount of radio frequency spectrum required to support the operation of a candidate concept.

2.13.1.1 Quantitative Measure of Effectiveness

Spectrum requirements output from EMC/EMV analysis.

2.13.1.2 Estimation Procedures

The EMC/EMV analysis will provide an output that lists the number of frequencies (by major band category) needed to deploy a candidate concept. Adjustments will be made, where appropriate, when nonstandard channel widths are employed.

2.13.1.3 Assumptions and Estimation Conditions

None.

2.13.2 Aspect: Flexibility of Frequency Allocation

This aspect examines each candidate system in terms of the flexibility offered in satisfying frequency allocation requirements.

2.13.2.1 Quantitative Measure of Effectiveness

Not applicable.

2.13.2.2 Estimation Procedures

This aspect will be a qualitative discussion of the flexibility a candidate concept offers system managers in the assignment of frequencies and channels to users. The discussion, as taken from the "desk-level" EMC/EMV supplementary evaluation, leads to conclusions which will consider international, national, allied, and other service frequency requirements and usage in the area of operations, as well as co-site needs.

2.13.2.3 Assumptions and Estimation Conditions

None.

2.14 AREA: ELECTROMAGNETIC COMPATIBILITY

EMC is the ability of communications-electronics equipments, subsystems, and systems, together with electromagnetic devices, to operate in their intended operational environments without suffering or causing unacceptable degradation due to unwanted electromagnetic radiation or response. EMC includes the following aspects:

- INTACS compatibility
- INTACS/other Army CE systems compatibility.

2.14.1 Aspect: INTACS Compatibility

Compatibility is defined as the capability of electronic equipment to operate in an environment in which only other radiating equipment of the system is operating, without significant performance degradation caused to or by the other system equipment. INTACS compatibility is measured in terms of the impact of unintentional electromagnetic interference on other equipment in INTACS.

2.14.1.1 Quantitative Measure of Effectiveness

Weighted average of EMC/EMV analysis compatibility subtest scores.

2.14.1.2 Estimation Procedures

The interference prediction model (IPM) derives compatibility scores for each net type after computing P(SO)s of communications links in nets operating in the presence of unintentional interference in the test bed. The MOE is a weighted arithmetical mean of these scores on the basis of the number of nets of the net type and a weighted value for the net type determined by communications analysts*:

$$WCP = \frac{\sum_{t=1}^{T} V_t N_t (CP)_t}{\sum_{t=1}^{T} V_t N_t} \qquad (0 \leq WCP \leq 100)$$

where

WCP = weighted average of EMC/EMV analysis compatibility subtest score

* Where applicable, these will be taken from DACE-CMS-E letter of 27 December 1973, Subject: Standards for Weighting Communications and Electronics Nets and Links in Simulated Force Models.

T = number of different discrete net types

t = a discrete net type, $t=1, 2, 3, 4, \ldots T$

V_t = values of net type t

N_t = number of nets of net type t in the system (N_t = 1, 2, 3, 4, ...)

$(CP)_t$ = compatibility subscore for net type t.

2.14.1.3 Assumptions and Estimation Conditions

None.

2.14.2 Aspect: INTACS/Other Army CE Systems Compatibility

This aspect is to determine the impact of unintentional electromagnetic interference caused by INTACS alternative concepts on other Army CE nets in the test bed (e.g., communications links associated with unattended ground sensors).

2.14.2.1 Quantitative Measure of Effectiveness

EMC/EMV analysis of other CE systems compatibility scores.

2.14.2.2 Estimation Procedures

The output of the "other CE systems compatibility" subtest is a listing of selected CE links that will suffer degradation, with a number indicating the relative degree of degradation.

2.14.2.3 Assumptions and Estimation Conditions

None.

3.0 UTILITY ALLOCATION

This section provides the US Army directive that established teams for the allocation of utility; it further provides the consolidated allocation that will be used in the INTACS effectiveness evaluation for the mid range time frame systems.

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S-20 February 1974

ATCD-CI-E

SUBJECT: Measures of Effectiveness (MOEs) for Integrated Tactical Communications System (INTACS) Study

Commander, US Army Logistics Center, Ft Lee, Virginia 23801
Commander, US Army Combined Arms Combat Development Activity, Ft Leavenworth Kansas 66027
Commander, US Army School/Training Center, ATTN: ATSO-CTD, Ft Gordon Georgia 30905

1. The effectiveness methodology for the INTACS Study requires determination of relative importance of identified measures of effectiveness (MOEs) through a hierarchical system of communications areas and aspects. This relative importance is to be reflected by the allocation of quantitative weights to each MOE. These weights are called utiles. The number of utiles allocated to each MOE is a key input for the INTACS Study. Enclosure 1 describes the allocation process. Enclosure 2 contains applicable definitions.

2. In order to ensure validity, the allocation of utiles to MOE must be made in light of the effect of the MOEs on communications in support of a combat situation. Allocations must be made only by experienced individuals; furthermore, it is required that more than one independent allocation of utiles be made to provide depth for analysis and to ensure that the results represent a balance of military judgement. Accordingly, four independent evaluations will be made by teams at the US Army Combined Arms Combat Development Activity (USACACDA), US Army Logistics Center (USALC), US Army Southeastern Signal School (USASESS), and at Headquarters, US Army Training and Doctrine Command (HQ TRADOC). Team members at USACACDA and HQ TRADOC will be combat arms officers with command experience at battalion or higher level. Teams at USASESS and USALC will consist of personnel with equivalent command experience within their specialties.

3. Teams will be organized as follows:

a. A minimum of six voting members, including the chairman.

b. A chairman of O-6 rank will be designated for each team.

c. Each team will document its organization and rules of procedure. These rules should be simple, should be few in number, and should include whatever methodology the team plans to use to make its allocation.

ATCD-CI-E
SUBJECT: Measures of Effectiveness (MOEs) for Integrated Tactical Communications System (INTACS) Study

4. Procedures for allocating utiles:

a. The procedure described in Enclosure 1 will be used as a basis for allocation of utiles.

b. The initial allocation will employ the areas, aspects, and MOEs defined in Enclosure 2. Having accomplished the initial allocation, each team (or member) may then make an independent analysis and allocation based on new, changed, or eliminated areas, aspects, and MOEs which it considers will produce a better set of measures to evaluate the effectiveness of communications systems. Every effort will be made to reduce the number of areas, aspects, and MOEs. New or changed areas, aspects, and MOEs must be defined.

c. Allocations will be made on the basis of military judgement. Each team will produce a "team" position.

5. The results arrived at by each team will be published as follows:

a. Allocation of utiles to the MOEs, as described in paragraph 4b above, will use the format in Enclosure 3. An allocation form will be prepared and submitted for each team member, as well as a form representing the views of the team as a whole. Each allocation will be supported by a brief rationale.

b. The allocation arrived at by the team based on elimination, change, or addition of areas, aspects, or MOEs will be documented in the same manner. Allocation criteria, rules of thumb, or other aids and guides used by the teams will be briefly described.

c. Completed reports documenting team results (to include individual member results) will be submitted to HQ TRADOC, ATTN: ATCD-CI-E, by close of business on 20 February 1974. The independent results of each team will be submitted. Recommendations and/or comments resulting from staffing may be submitted as an addendum to the team report.

6. In order to assist, this headquarters is prepared, upon request, to provide an orientation briefing on methodology and to answer questions for the teams prior to their allocation effort. Point of contact for this headquarters is LTC Foster, AUTOVON 680-3465.

7. The results of the four independently conducted allocation actions will be analyzed and correlated by this headquarters prior to presentation to the INTACS contractor and the DA Study Advisory Group.

FOR THE COMMANDER:

3 Encl:
1. Utile Allocation
2. Definitions
3. Utile Format

ROBERT C. McALISTER
Major General, GS
Deputy Chief of Staff
for Combat Developments

CF: w/encl
Comdt, USASESS

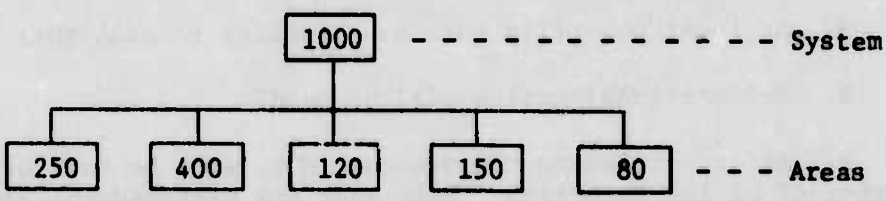
ENCLOSURE 1

UTILE ALLOCATION

1. A utile is a dimensionless quantity used to weigh the measures of effectiveness (MOEs) that will form a basis for evaluation of the alternative communications systems.

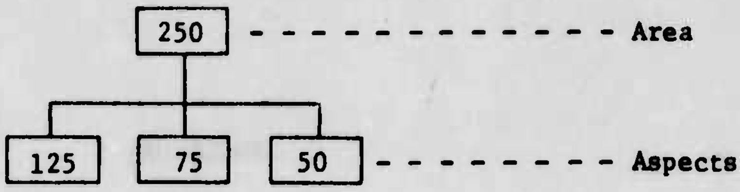
2. The assignment of utiles to MOEs is a subjective process. The number of utiles assigned to an MOE designates the relative importance of the MOE when compared against other MOEs. As an example, if MOE-1 has been assigned 10 utiles and MOE-2 has been assigned 5 utiles, this indicates that MOE-1 is twice as important as MOE-2.

3. For the purposes of this exercise, a communications system is assigned 1000 utiles. The allocation process is a method by which this 1000 utiles is divided among the various MOEs so that the number of utiles assigned to an MOE will reflect its relative contribution to communications systems effectiveness. The process is accomplished by successive assignment of utiles to areas, aspects, and finally to MOEs. Distribution of utiles is separated into three stages to limit the number of elements that must be considered at one time. The first stage is to distribute the total utiles among the fourteen areas. The basis for this allocation is the relative importance of each communications system area under consideration. As an example, if there were only five areas, the breakout might look like this:



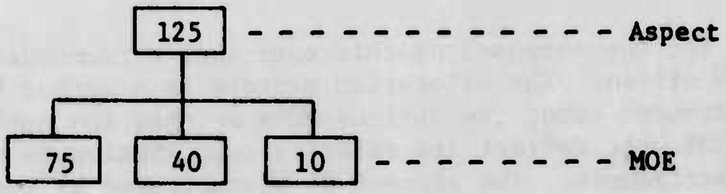
The number of utiles assigned to each area is not expected to be equal, but should be apportioned to each area in accordance with its relative importance. The sum of the utiles of all areas must equal 1000.

In the second stage, these area utiles are subdivided and allocated to aspects within each area. If a particular area has three aspects, the breakout of utiles might look like this:



In this case, the total number of utiles assigned to the three aspects equals the number assigned to the parent area (i.e., 250). As in the case of areas, note that the sum of all the utiles assigned to all aspects of all areas must equal 1000.

In the third stage, using a similar procedure, the MOE utiles are derived from aspect utiles. As an example, for an aspect with three MOEs, the breakout might look like this:



The sum of the three MOEs assigned to this aspect will equal that of its parent aspect. As for areas and aspects, the sum of all the utiles assigned to all MOEs must equal 1000.

4. Additional procedures:

a. At least one utile must be allocated to each MOE.

b. No fractional utiles will be used.

c. After completing the process, MOEs will be rank-ordered based on the number of utiles allocated. MOEs that are assigned the same utile value will be considered to have equal rank of relative importance. If this rank-ordering places an MOE in a relative rank that is considered to be out of line, then utiles must be reallocated. This is mostly done by recycling the entire process. Therefore, it may be necessary to complete several iterations of the entire process in order to arrive at an allocation that will yield the rank order deemed appropriate by the evaluation (or team).

d. If, after completion of the entire process described above for the initial 14 areas and 63 MOEs, the team (or an individual) decides on a different (preferably smaller) set of MOEs as a better measure of effectiveness, then a similar procedure should be followed to allocate utiles and rank-order the MOE.

ENCLOSURE 2

DEFINITIONS

Area:	Electromagnetic Compatibility - the ability of radio communications equipment to function in an operational environment without suffering degradation through mutual interference.
Aspect and MOE:	Unintentional interference on a radio from other radios within the system.
Aspect and MOE:	Unintentional interference on a radio net from equipment of other friendly forces in the area.
Area:	Flexibility - the ability of the communications system to expand, contract, and/or reorganize to satisfy a variety of communications requirements.
Aspect and MOE:	Ability of the system to function in various operational environments and on various terrains.
Aspect and MOE:	Ability of the system to adapt to a changing force structure.
Aspect and MOE:	Ability of the system to meet a commander's change in mission.
Aspect:	Impact on system performance from increasing the volume of traffic for computer systems (data traffic).
MOE:	System degradation caused by increased sensitivity to disturbances. (Data traffic is more sensitive than voice to interference. This could be caused by atmospheric conditions or enemy jamming, or it could be unintentional interference from other friendly equipment in the area. Typically, data traffic would require retransmissions more frequently than would voice traffic.)
MOE:	Quality of transmissions for data systems such as TOS and TACFIRE.
Aspect and MOE:	Ability of the communications system to accommodate additional subscribers.

Aspect and MOE: Ability of the system to satisfy the communications requirements of a unit on a special mission.

Aspect and MOE: Total time of interrupted service for subscribers affected by CP displacement.

Aspect and MOE: Ability of the system to operate in varied deployments.

Aspect and MOE: Increased system performance resulting from using equipment modularity.

Area: Logistical Support - the ability to satisfy support requirements of the communications system in terms of power sources, spare equipment, and spare parts.

Aspect: Ease of providing required parts support.

MOE: Degree to which critical equipment in the system is not operationally ready due to the nonavailability of required parts (NORS rate).

MOE: Storage requirements to maintain the necessary spare parts inventory in support of the communications system.

MOE: Ability to respond to a need for spare parts. (This will be measured in terms of stockage-levels maintained and locations of parts/maintenance support centers with respect to the using units.)

Aspect and MOE: Generator requirements for communications equipment.

Area: Maintainability - the ability to provide the necessary maintenance for the communications system.

Aspect: Ease of providing preventive maintenance.

MOE: Total manhours required to provide preventive maintenance for the system.

MOE: Percentage of preventive maintenance that can be performed without special test equipment.

MOE: Storage requirements for spare parts needed for preventive maintenance.

MOE: Ease of providing preventive maintenance measures in terms of:

- Required downtime that must be scheduled for the maintenance;
- Physical location (remoteness) of deployed equipment.

Aspect:	Ease of providing corrective maintenance.
MOE:	Total manhours required to provide corrective maintenance for the system.
MOE:	Percentage of corrective maintenance that can be performed without special test equipment.
MOE:	Storage requirements for spare parts needed for corrective maintenance.
MOE:	Degree to which equipment is not operationally ready and awaiting maintenance (NORM rate).
MOE:	Impact of physical location (remoteness) of deployed equipment on the ease of providing corrective maintenance for that equipment.
Aspect:	Ease of maintaining computer-assisted parts of the communications system.
MOE:	Manhours and skill levels required for normal computer maintenance.
MOE:	Manhours and skill levels required for special maintenance.
MOE:	Ease of providing this computer maintenance measured in terms of: • Off-site personnel requirements • Special debugging side required.
Area:	Mobility - the ability of the system to provide users a communications capability during movement.
Aspect and MOE:	Physical setup and teardown times for critical equipment and major assemblages of equipment.
Aspect:	Ability to communicate during movement.
MOE:	Grade of service during movement.
MOE:	Change in message quality during movement.
Area:	Operability - the ease of using the communications system so that it adequately serves the needs of the user.
Aspect:	Degree of difficulty in system operation.

MOE: Number of personnel, by MOS, required to operate the communications system.

MOE: Ease of placing a telephone call.

Aspect and MOE: Service features such as:

- ° Command override
- ° Conference calls
- ° Abbreviated dialing.

Area: Quality of Service - the ability of the system to provide the user with successful first-try call initiation in a timely manner and with intelligible message transmission.

Aspect and MOE: Grade of service (probability that a telephone or teletype message will not be blocked).

Aspect and MOE: Speed of service (probability that a teletype message will be received within the acceptable time specified by JCS for the precedence of that message).

Aspect and MOE: Information quality (probability that the received message will be intelligible).

Area: RF Spectrum Requirements - the number and width of radio frequency channels required to implement the operation of a given radio system. This number is a function of the number of nets to be formed and is also dependent upon equipment range and the location of net users.

Aspect and MOE: Amount of radio frequency spectrum required to support the operation of the communications system. (If the number of separate frequency assignments required within the system is too high, the frequencies allocated may be close to one another and interference by other users in the system will increase.)

Aspect and MOE: Degree of flexibility in the assignment of frequencies by systems managers.

Area: Reliability - the ability of the system to have equipment available and operational when needed.

Aspect and MOE: Availability of the system to the user considering uptime and downtime of necessary equipment.

Area: Security - the ability of the system to deny the enemy the capability of deriving useful intelligence from communications transmissions.

Aspect and MOE:	Ability of the system to provide increased secure communications.
Aspect and MOE:	Limitations imposed upon the system due to increased requirements when security is provided (e.g., increased size and weight of equipment, additional logistical support requirements, etc.).
Aspect and MOE:	Ability of the system to provide the user with the capability of secure communications with allied or interservice forces.
Aspect and MOE:	Ability of the system to accommodate an increase in secure subscribers.
Aspect and MOE:	Ease of restoring system security after compromise.
Aspect and MOE:	Percent of subscribers provided with total secure service.
Aspect and MOE:	Ability of the radio net to avoid enemy interception.
Area:	Standardization - the degree to which the communications system uses common, compatible, or interchangeable equipment.
Aspect and MOE:	Number of categories of communications equipment.
Area:	Survivability - the ability of the system to function during and after destructive physical and electronic attack.
Aspect:	Impact of destruction of communications system nodes.
MOE:	Network redundancy (number of nodes that must be destroyed before communications service drops to an unacceptable level).
MOE:	Subscriber loss resulting from nodal destruction.
MOE:	Alternate capabilities inherent within the system to minimize the impact of destruction of communications system nodes (e.g., alternate routing of traffic through other nodes, alternate nodes of transmission, etc.).
Aspect and MOE:	Disruptive impact of enemy jamming.
Area:	Transportability - the ease of transporting communications equipment.
Aspect:	Size and weight of communications equipment, support parts, and power sources.

MOE: Volume of equipment and power sources.

MOE: Weight of equipment and power sources.

Aspect and MOE: Organic transport capability (i.e., percentage of the communications system that can be transported by organic means).

Aspect and MOE: Portability of equipment; for example:

- Can be suspended from belt, carried in a pocket, operated on-the-move;
- Can be transported by one man, but cannot be operated on-the-move;
- Can be mounted on a vehicle (such as a jeep) and operated on-the-move.

Area: Vulnerability - the degree to which the communications system is susceptible to destructive physical and electronic attack.

Aspect: Susceptibility to detection and physical destruction.

MOE: Distance of important nodes from the enemy. (The actual measure of effectiveness evaluates the ability of the communications system to locate a node as far away from the enemy as possible while still providing all services required by the users.)

MOE: Susceptibility of the communications system to physical destruction.

MOE: Susceptibility of transmitters to direction-finding by the enemy.

ENCLOSURE 3

ALLOCATION OF UTILES TO AREAS

1. Electromagnetic compatibility . . . . ______
2. Flexibility . . . . ______
3. Logistical support. . . . . ______
4. Maintainability . . . . ______
5. Mobility. . . . . ______
6. Operability . . . . ______
7. Quality of service. . . . . ______
8. RF spectrum requirements. . . . . ______
9. Reliability . . . . ______
10. Security. . . . . ______
11. Standardization . . . . ______
12. Survivability . . . . ______
13. Transportability. . . . . ______
14. Vulnerability . . . . ______

ALLOCATION OF UTILES TO ASPECTS

1. Electromagnetic compatibility

    INTACS compatibility . . . . ________

    INTACS/other system compatibility. . . . . ________

2. Flexibility

    Function in varying operational environments . . . . ________

    Changes in force structure . . . . ________

    Change in mission. . . . . ________

    Varying ratios of traffic. . . . . ________

    Impact of added subscribers. . . . . ________

    System modularity. . . . . ________

    Downtime for CP displacement . . . . ________

    Operation in varying deployments . . . . ________

    Hardware modularity. . . . . ________

3. Logistical support

    Required parts support . . . . ________

    Power requirements . . . . ________

4. Maintainability

    Provision of preventive maintenance. . . . . ________

    Provision of corrective maintenance. . . . . ________

    Provision of software update . . . . ________

5. Mobility

Setup/teardown time. ________

Communication during moves . . . . ________

6. Operability

Difficulty of system operation . . . . ________

Service features . . . . ________

7. Quality of service

Grade of service . . . . ________

Speed of service . . . . ________

Information quality. ________

8. RF spectrum requirements

RF bandwidth requirements. . . . . ________

Flexibility of frequency allocation. . . . . ________

9. Reliability

System availability. ________

10. Security

Provision for increased secure communications. . . . ________

Limitations due to increased security. . . . . ________

Ratio of secure to nonsecure users . . . . ________

Interface security requirements. . . . . ________

Restoration after compromise . . . . ________

Degree of security . . . . ________

Interceptibility . . . . ________

11. Standardization

Multiplicity of CE equipment . . . . ________

12. <u>Survivability</u>

Impact of nodal destruction. . . . . ________

Impact of jamming. ________

13. <u>Transportability</u>

Equipment size and weight. . . . . ________

Vehicle requirements . . . . ________

Portability. . . . . ________

14. <u>Vulnerability</u>

Physical destruction . . . . ________

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ALLOCATION OF UTILES TO MOE

1. Electromagnetic compatibility

INTACS compatibility

EMC/EMV INTACS compatibility. . . . . ______

INTACS/other system compatibility

EMC/EMV other system compatibility. . . . . . . ______

2. Flexibility

Function in varying operational environments

Operational environment . . . . ______

Changes in force structure

Force structure . . . . ______

Change in mission

Change in mission . . . . ______

Varying ratios of traffic

Variation of data/voice traffic ratio . . . . . ______

Data transmissions. . . . . ______

Impact of added subscribers

Additional subscribers. . . . . ______

System modularity

System modularity . . . . ______

Downtime for CP displacement

Downtime for CP displacement. . . . . ______

Operation in varying deployments

Various deployments . . . . ________

Hardware modularity

Hardware modularity . . . . ________

3. Logistical support

Required parts support

NORS rate . . . . ________

Volume of parts inventory . . . . ________

Ease of support . . . . ________

Power requirements

Total power . . . . ________

4. Maintainability

Provision of preventive maintenance

Manhours preventive maintenance . . . . ________

Maintenance hours without equipment . . . . ________

Volume of preventive maintenance parts. . . . . . ________

Ease of preventive maintenance. . . . . ________

Provision of corrective maintenance

Manhours corrective maintenance . . . . ________

Maintenance hours without equipment . . . . ________

Volume of corrective maintenance parts. . . . . . ________

NORM rate . . . . ________

Ease of corrective maintenance. . . . . ________

Provision of software update

Manhours/language - continual . . . . ________

Manhours/language - special . . . . ________

Ease of software maintenance. . . . . ________

5. Mobility

Setup/teardown time

Physical setup/teardown time. . . . . ______

Communication during moves

GOS during a move . . . . ______

Change in message quality . . . . ______

6. Operability

Difficulty of system operation

Ease of placing a call. . . . . ______

Ease of maintaining a directory . . . . ______

Number of personnel . . . . ______

Service features

Service features. . . . . ______

7. Quality of service

Grade of service

Grade of service. . . . . ______

Speed of service

Speed of service. . . . . ______

Information quality

Information quality . . . . ______

8. RF spectrum requirements

RF bandwidth requirements

EMC/EMV spectrum requirements . . . . ______

Flexibility of frequency allocation

RF spectrum flexibility . . . . ______

9. Reliability

System availability

System availability . . . . ________

10. Security

Provision for increased secure communications

Ability to increase security. . . . . ________

Limitations due to increased security

Limitations of increase . . . . ________

Ratio of secure to nonsecure users

Ratio of secure to nonsecure users. . . . . . . ________

Interface security requirements

Interface security requirements . . . . ________

Restoration after compromise

Compromise restoral . . . . ________

Degree of security

Number of subscribers end-to-end secure . . . . ________

Interceptibility

Interceptibility. . . . . ________

11. Standardization

Multiplicity of CE equipment

Number of equipment categories. . . . . ________

12. Survivability

Impact of nodal destruction

Number of nodes destroyed to reduce GOS to specified level . . . . ________

Subscriber loss due to nodal destruction. . . . ________

Alternate capabilities. . . . . ________

Impact of jamming

EMC/EMV jamming vulnerability . . . . ________

13. Transportability

Equipment size and weight

Volume of system. . . . . ________

Weight of system. . . . . ________

Vehicle requirements

Transport vehicles organic. . . . . ________

Portability

Portability . . . . ________

14. Vulnerability

Susceptibility to detection and physical destruction

Distance of nodes from the enemy. . . . . ________

Susceptibility to physical destruction. . . . . ________

Susceptibility to direction-finding . . . . . . ________

DEPARTMENT OF THE ARMY
HEADQUARTERS UNITED STATES ARMY SOUTHEASTERN SIGNAL SCHOOL
FORT GORDON GEORGIA 30905

IN REPLY REFER TO

ATSO-CTD-CS

8 April 1974

SUBJECT: Approved Utile Allocation for Task III

Martin-Marietta Corporation
ATTN: Mr. Robert Cuthill
P. O. Box 7128
Fort Gordon, Georgia 30905

APR 08 1974
INTACS CONTRACT

1. Inclosed is the USATRADOC approved allocation of utiles for use in Task V and for inclusion in the Task III Report.

2. The values assigned to the various MOE are not considered to be fixed, however, any changes that are desired must be approved by the COR and if major revisions are intended, HQ USATRADOC must be informed.

1 Incl
as

GENE R. FARMELO
Captain, Signal Corps
Contracting Officer's Representative

DEPARTMENT OF THE ARMY
HEADQUARTERS UNITED STATES ARMY TRAINING AND DOCTRINE COMMAND
FORT MONROE, VIRGINIA XXXX 23651

ATCD-CI-E

2 APR 1974

SUBJECT: Measures of Effectiveness (MOE) for Integrated Tactical Communications System (INTACS) Study

Commander
US Army School/Training Center &
Ft Gordon
Fort Gordon, GA 30905

Attached as Inclosure 1 are TRADOC approved Measures of Effectiveness (MOE) for use in the INTACS Study.

FOR THE COMMANDER:

1 Incl
as

MICHAEL A. RANDALL
MAJ, AGC
Asst AG

CF: w incl
~~Comdt~~, USASESS
ATTN: ATSO-CTD-CS

ALLOCATION OF UTILES TO AREAS AND MOES

	AREA	MOE
1. Quality of service	114	
a. Grade of service		34
b. Speed of service		33
c. Information quality		47
2. Operability	93	
a. Ease of placing a call		21
b. Ease of maintaining a directory		11
c. Number of personnel		25
d. Service features		36
3. Reliability	129	
System availability		129
4. Maintainability	84	
a. Manhours preventive maintenance		13
b. Maintenance hours without equipment		7
c. Volume of preventive maintenance parts		5
d. Ease of preventive maintenance		12
e. Manhours corrective maintenance		6
f. Maintenance hours without equipment		5
g. Volume of corrective maintenance parts		4
h. NORM rate		9

		AREA	MOE
	i. Ease of corrective maintenance		6
	j. Manhours/language - continual		5
	k. Manhours/language - special		5
	l. Ease of software maintenance		7
5.	<u>Electromagnetic compatibility</u>	50	
	a. EMC/EMV INTACS compatibility		32
	b. EMC/EMV other system compatibility		18
6.	<u>Logistical support</u>	79	
	a. NORS rate		18
	b. Volume of parts inventory		8
	c. Ease of support		12
	d. Total power		41
7.	<u>Security</u>	71	
	a. Ability to increase security		15
	b. Limitations of increase		12
	c. Ability of the system to expand		8
	d. Interface security requirements		8
	e. Compromise restoral		9
	f. Number subscribers end-to-end secure		8
	g. Interceptibility		11
8.	<u>Flexibility</u>	95	
	a. Operational environment		13
	b. Force structure		13
	c. Change in mission		12
	d. Variation of data/voice traffic ratio		6

	AREA	MOE
e. Data transmissions		7
f. Additional subscribers		11
g. System modularity		5
h. Downtime for CP displacement		12
i. Various deployments		10
j. Hardware modularity		6
9. Mobility	75	
a. Physical setup/teardown time		38
b. GOS during a move		17
c. Change in message quality		20
10. Transportability	46	
a. Volume of system		8
b. Weight of system		8
c. Transport vehicles organic		17
d. Portability		13
11. RF spectrum requirements	41	
a. EMC/EMV spectrum requirements		22
b. RF spectrum flexibility		19
12. Standardization	39	
Number of equipment categories		39
13. Survivability	45	
a. Number of nodes destroyed to reduce GOS to specified level		8
b. Subscriber loss due to nodal destruction		8
c. Alternate capabilities		5
d. EMC/EMV jamming vulnerability		26

		AREA	MOE
14.	Vulnerability	39	
	a. Distance of nodes from the enemy		10
	b. Susceptibility to physical destruction		11
	c. Susceptibility to direction-finding		18
		1000	1000

RANK CORRELATION TEST FOR MOES

The amount of correlation between all possible sets of paired ranks was determined by use of Spearman's formula for rank correlation. The MOE values and corresponding ranks are shown in Table 1. The computed values for the rank correlation (r) for each possible paired combination of data submitted by the four participating organizations are shown below.

Formula:

$$r = 1 - \frac{6 \Sigma d^2}{n(n^2-1)}$$

where

d = difference in paired ranks

n = number of paired ranks.

TRADOC vs CACDA	r = 0.609
TRADOC vs LOGS	r = 0.511
TRADOC vs SESS	r = 0.673
CACDA vs LOGC	r = 0.639
CACDA vs SESS	r = 0.767
LOGC vs SESS	r = 0.689

Null hypothesis: The paired sets of rankings are independent.

Alternate hypothesis: The paired sets of rankings are dependent (or correlated). The critical value for Alpha = 0.01 is less than 0.48.

Conclusion: Since each computed r is greater than 0.48, the null hypothesis of independence is rejected in favor of the alternate hypothesis of dependence between all possible paired rankings.

TABLE 1. MOE and Ranks

	TRADOC	Rank	CACDA	Rank	LOGC	Rank	SESS	Rank
1.								
a.	30	9	30	9	40	5	37	6
b.	40	7.5	10	32	20	14	38	5
c.	70	2	30	9	60	2	28	8.5
2.								
a.	50	4	15	22.5	20	14	29	7
b.	15	22	5	48.5	10	34	12	26
c.	25	11	20	16.5	30	8	26	10
d.	40	7.5	10	32	40	5	28	8.5
3.								
	120	1	125	1	130	1	141	1
4.								
a.	15	22	10	32	15	22.5	12	26
b.	10	31	5	48.5	5	51	10	33
c.	5	45	5	48.5	5	51	6	57.5
d.	20	15	10	32	10	34	9	39.5
e.	6	40.5	6	39	5	51	9	39.5
f.	5	45	3	59	5	51	8	47
g.	4	50	3	59	5	51	5	59.5
h.	15	22	10	32	5	51	8	47
i.	10	31	3	59	5	51	7	53.5
j.	4	50	5	48.5	5	51	8	47
k.	6	40.5	5	48.5	5	51	6	57.5
l.	10	31	5	48.5	5	51	7	53.5

	TRADOC	Rank	CACDA	Rank	LOCC	Rank	SESS	Rank
5.								
a.	51	3	40	4	20	14	18	16
b.	49	5	25	12	10	34	19	14
6.								
a.	20	15	15	22.5	20	14	18	16
b.	8	36	5	48.5	10	34	9	39.5
c.	12	26.5	10	32	15	22.5	10	33
d.	45	6	20	16.5	40	5	39	3.5
7.								
a.	18	18	20	16.5	10	34	12	26
b.	16	19	10	32	15	22.5	8	47
c.	10	31	5	48.5	10	34	7	53.5
d.	6	40.5	5	48.5	10	34	10	33
e.	13	25	5	48.5	10	34	9	39.5
f.	8	36	10	32	5	51	10	33
g.	4	50	15	22.5	20	14	7	53.5
8.								
a.	11	28	75	2	10	34	17	18.5
b.	9	34	15	22.5	15	22.5	14	21.5
c.	12	26.5	10	32	5	51	14	21.5
d.	3	53.5	5	48.5	10	34	7	53.5
e.	1	58.5	5	48.5	10	34	5	59.5
f.	8	36	10	32	15	22.5	11	29.5
g.	3	53.5	5	48.5	5	51	8	47
h.	6	40.5	20	16.5	5	51	18	16

	TRADOC	Rank	CACDA	Rank	LOGC	Rank	SESS	Rank
i.	7	38	10	32	10	34	12	26
j.	5	45	5	48.5	5	51	8	47
9.								
a.	15	22	40	4	35	7	39	3.5
b.	20	15	40	4	15	22.5	16	20
c.	20	15	20	16.5	20	14	10	33
10.								
a.	5	45	10	32	5	51	11	29.5
b.	5	45	10	32	5	51	9	39.5
c.	20	15	15	22.5	5	51	17	18.5
d.	15	22	20	16.5	10	34	9	39.5
11.								
a.	25	11	25	12	15	22.5	23	11.5
b.	10	31	25	12	20	14	23	11.5
12.								
	25	11	35	6.5	55	3	41	2
13.								
a.	1	58.5	5	48.5	10	34	9	39.5
b.	1	58.5	5	48.5	5	51	7	53.5
c.	2	55.5	5	48.5	20	14	9	39.5
d.	4	50	35	6.5	25	9	21	13
14.								
a.	2	55.5	15	22.5	10	34	8	47
b.	1	58.5	5	48.5	20	14	12	26
c.	4	50	30	9	15	22.5	13	23

APPENDIX B

COST METHODOLOGY

APPENDIX B
COST METHODOLOGY

This appendix contains the cost methodology to be used to evaluate the alternatives during Task V. Section 1.0 provides the specific formula, cost-estimating relationships (CERs), or criteria used to estimate each cost element in the LCC model. The equations used to aggregate the cost elements into various categories are presented in Section 2.0, while the cost elements are defined in Section 3.0 of this appendix.

1.0 LIFE-CYCLE COST MODEL

Total LCC is the cost of ownership from the day a system/equipment is conceived to the day it is phased out of use. Included are the R&D cost, the investment cost, and the total O&M cost incurred to support the equipment during use. The total life-cycle cost is computed by using a series of simple aggregating equations of the type shown below:

Total LCC = R&D Cost
+ Investment Cost
+ (Annual O&M Cost x Years Equipment is in Use).

1.1 RESEARCH AND DEVELOPMENT COST

Research and development cost includes the costs for applied research, engineering design, analysis, development, and testing that can be related to a specific communications system. The effort from which these costs derive usually occurs within advanced development, engineering development, and operations systems development of the R&D cycle. Elements included in R&D costs are shown in Figure B-1, and are defined in Section 3.0.

The equipment that will be part of the concepts for the mid range time frame will typically be items already fielded or in various stages of development. For existing equipment, the R&D cost is considered sunk, while that for future developments will be obtained from actual or proposed outlays.

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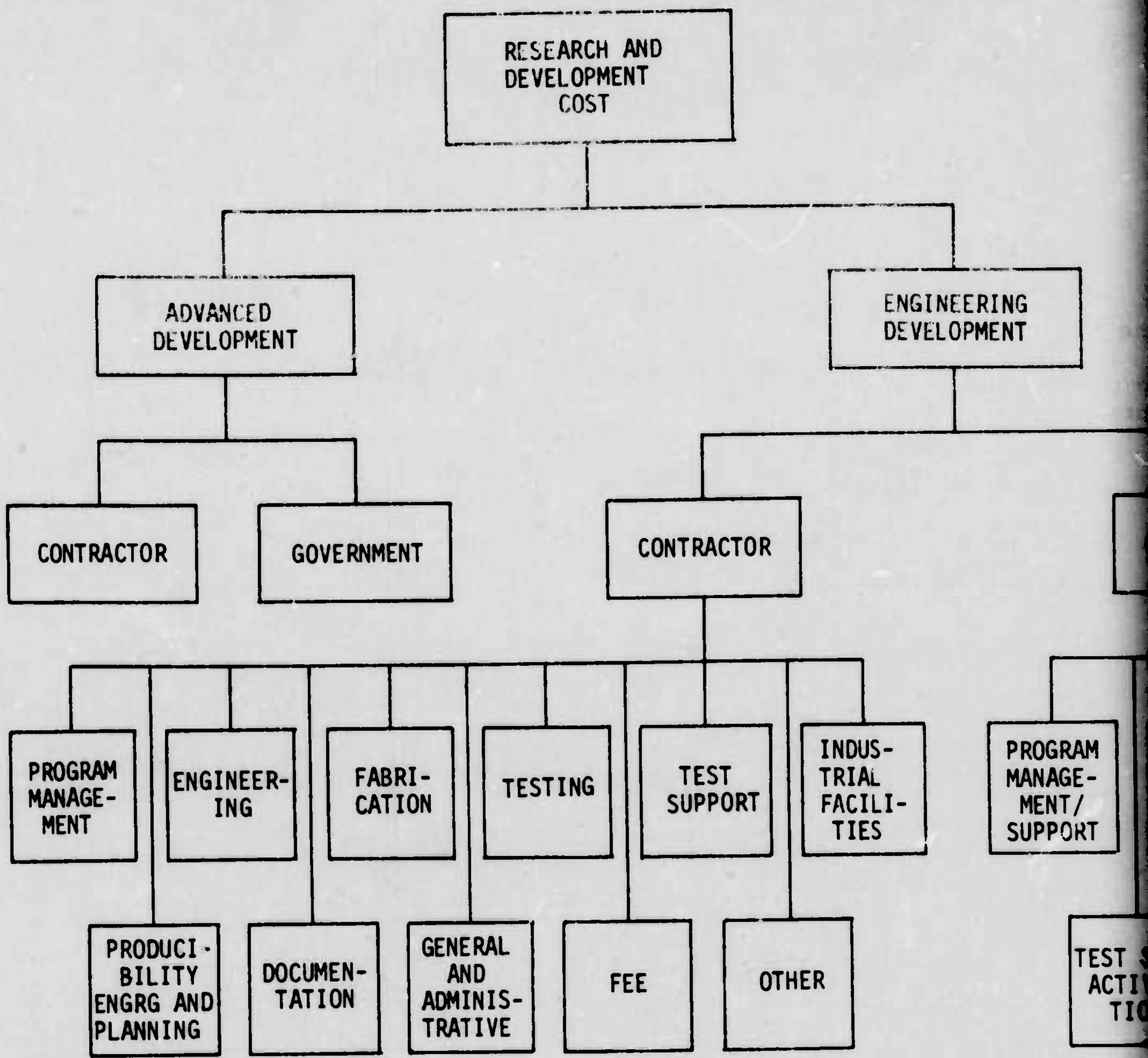
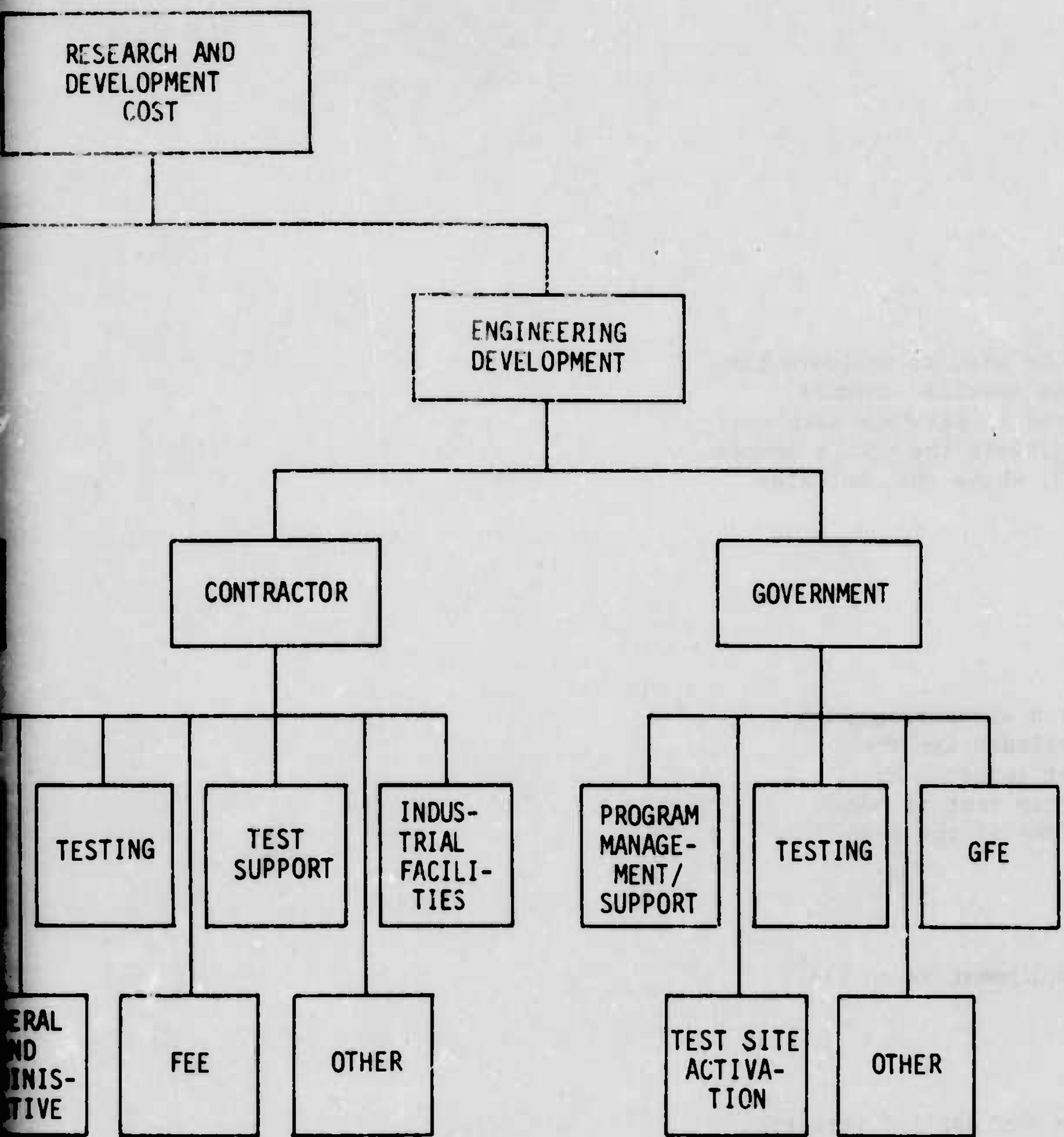


FIGURE B-1 Research and Development Cost Breakdown



B-1 Research and Development Cost Breakdown

1.2 INVESTMENT COST

Investment cost refers to those program costs required beyond the developmental phase to introduce into operational use a new capability; to procure initial, additional, or replacement equipment for operational forces; or to provide for major modifications of an existing capability. Nonrecurring costs refer to investment costs incurred one time during the production phase, although they can recur if there is a change in design, contractor, or manufacturing process. Recurring costs include production costs that recur with each unit produced, thus tending to be subject to a learning curve in which the cost per unit decreases as quantity increases. The cost incurred in the latter category terminates with the satisfactory turnover of an operationally usable system to the using command or organization. Elements included in investment costs are presented in Figure B-2 and are defined in Section 3.0 of this appendix.

Figure B-2 is placed at the end of this subsection (page B-11). The reader is asked to fold out this figure to conveniently see the relationships between the investment cost elements as he reads the details of each in succeeding paragraphs. The equation for estimating investment cost is as follows:

Total Investment Cost = Nonrecurring Investment Cost
+ Recurring Investment Cost

where

- Nonrecurring Investment Cost = Inventory Introduction + Initial Provisioning + Initial Tolling and Test Equipment + Instructor Training + Initial Production Facilities;

- Recurring Investment Cost = Total Hardware Cost + First Destination Transportation + Initial Training + Site Activation + Acceptance Testing + Transportation from First Destination.

Components, operational ready float, repair cycle float, and prepositioned war reserves are all covered within the above terms.

The specific formulas, CERs, or criteria to be used to estimate nonrecurring and recurring investment costs are detailed in Subsections 1.2.1 and 1.2.2, respectively.

1.2.1 Nonrecurring Investment Cost

The individual elements of nonrecurring investment cost, as indicated above, are calculated by using the following formulas:

- Inventory Introduction Cost for New Line Items = Number of Parts in Inventory x Appropriate Value from the following table (source: Reference 4):

Unit Dollar Value	Introduction	1st Year Costs
Super High (over $25,000)	$680	$1070
High ($10,000 - $24,999)	$530	$ 770
Medium ($2,500 - $9,999)	$450	$ 580
Low (under $2,500)	$430	$ 460
Average Cost*	$480	$ 510

- Inventory Introduction Cost (for others) = 0

- Initial Provisioning Cost = 15 Percent x Hardware Unit Cost x First-Year Total Build + 10 Percent x Hardware Unit Cost x Second-Year Total Build (source: Reference 4);

- Initial Tooling and Test Equipment Cost - To be estimated on the basis of equipment complexity and guidance provided by ECOM;

- Instructor Training Cost = 5 Percent x Hardware Unit Cost x Total Build (source: Reference 16);

- Initial Production Facilities Cost = To be estimated based on the nature of the new equipment and guidance provided by ECOM.

1.2.2 Recurring Investment Cost

The individual elements of recurring investment cost are calculated by using the following formulas:

- Total Hardware Cost = Hardware Unit Cost x Total Build** (source: by definition);

- First Destination Transportation Cost*** = 1.5 Percent x Hardware Unit Cost x Total Build (source: Reference 4);

- Transportation Cost from First Destination = (0.5 Percent x Hardware Unit Cost x Total Build) + 1 Percent x Initial Provisioning Cost (source: Reference 34);

---

* Represents a weighted supply requirement cost per line item plus cataloging and maintenance costs. Use this number in the absence of specific values.

** For the purposes of the INTACS evaluation, total build is defined as the total of items to be procured during the time frame under consideration.

*** This is the factor presently used in the PEMA "standard pricing" procedure. If standard prices from the Army Data File or the SB 700-20 are used as hardware cost, these transportation costs are already included.

* Initial Training Cost = Number of Operators x Number of Hours of Training x (Course Costs/Hour + Training Salary/Hour) + Number of Maintenance People x Number of Weeks of Training x (Course Costs/Week + Training Salary/Week);

* Site Activation Cost = 6 Percent x Hardware Unit Cost x Total Build (source: Reference 35);

* Acceptance Test Cost = Appropriate Figure from Table B-1 (source: Reference 4).

The total hardware cost includes all the hardware built and required to operate the communications system under OPA funds. Included are all the individual costs of equipments, vehicles, power sources, peripheral equipments, and crypto devices that are integral to the communications system. The unit cost for each individual equipment is that price as identified in the Army Item Inventory Data File or the SB 700-20, or as estimated by analogy or CERs. Hardware unit cost will be estimated using the form presented in Figure B-3, the components of which are defined as follows:

* Basic Unit - Equipment under analysis as produced to a type-classified configuration. Included are all receivers, transmitters, logic, synthesizers, amplifiers, and handsets required to make an integral piece of equipment (with antennas, power supplies, and all ancillary or support pieces separately identified, if possible).

* Antenna(s) - Individual pieces of equipment not integral to the basic unit and having their own type classification.

* Power Source - Batteries, generators, and commercial power required to operate the basic equipment. For this analysis, commercial power was considered free of charge.

* Vehicle - Vehicles for the CE equipment that are 100 percent associated with and used for transporting the CE equipment.

* Trailer - Cargo trailers, or support trailers used solely to support or transport CE equipment, antennas, and generators.

* Shelter - Housing for the CE equipment that is 100 percent associated with and used to contain the equipment.

* Air Conditioner - Air conditioners common to the CE equipment that are 100 percent used in the operation of the basic unit.

* Remotes - Equipment required to operate the basic equipment from a distant location. This includes all cables.

TABLE B-1
Estimated Acceptance Testing Costs

EQUIPMENT	COST
Radios, Aircraft	
Airborne: VHF, UHF, SSB	$130,000*
Ground Station: UHF, VHF, SSB	$122,000
Radios, Manpack	$110,000
Radios, Mobile or Vehicular	$ 80,000
Radios, Fixed Station (transmitting and receiving)	$34,000 to $73,000
Telephone Sets, Automatic and Manual Switchboards	$32,000 to $73,000
Radios, Terminal Sets, Relays (tropospheric)	$68,000 to $202,000
Radios, Communications Centrals (repeaters)	$242,000
Radio Components (receivers, modems, etc.)	$ 40,000
Teletypewriter Sets (systems, terminals)	$ 65,000
Centrals, Communications (i.e., SATCOM, data)	$225,000

* Includes flight testing.

Equipment Name ____________________

Total Hardware Cost* $ __________
Total Build __________
Hardware Unit Cost __________

Description	Item	Unit Cost	Quantity	Year Produced	Company
Basic Unit					
Antenna(s)					
Power Source					
Vehicle					
Trailer					
Shelter					
Air Conditioner					
Remotes					
Facility/Land					
Crypto/Ancillary					
Leasing Costs					

* Total hardware cost is the sum of unit costs times total quantity built and/or to be built. Operator input to be manually completed.

** Indicates that investment costs have been included/amortized in hardware unit cost.

*** Indicates that element of equipment is included in basic unit cost and cannot be identified separately.

FIGURE B-3 Hardware Cost Form

- Facility/Land - Includes all acquisition of real estate, site preparation, and installations fabricated to provide an operational facility.

- Crypto/Ancillary - Equipment not integral to the basic unit and assigned to the basic unit to provide crypto or other modes of communication.

- Leasing Costs - Costs for leasing the lines used for communication of any other facility leased for the use of the equipment.

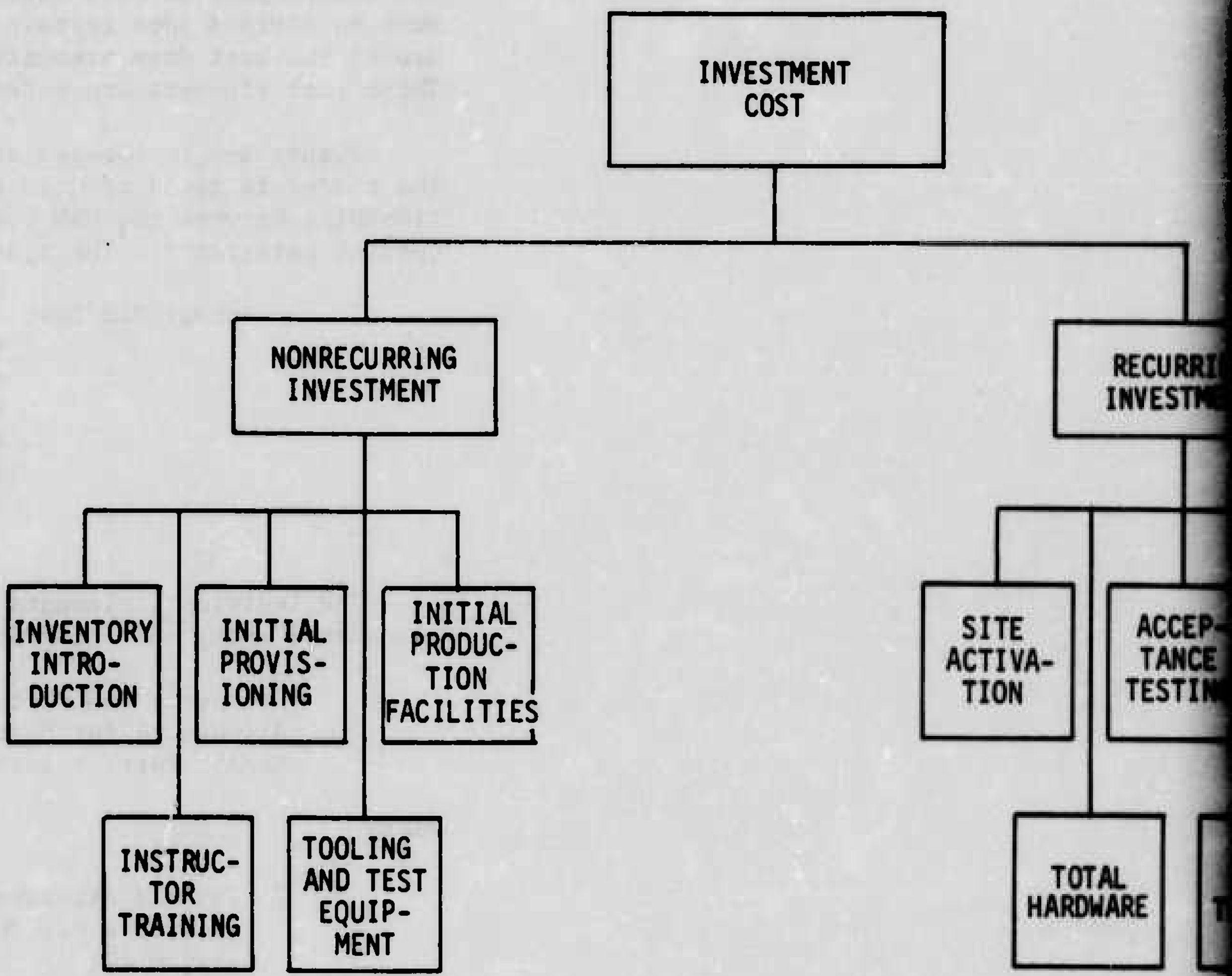


FIGURE B-2 Investment Cost Breakdown

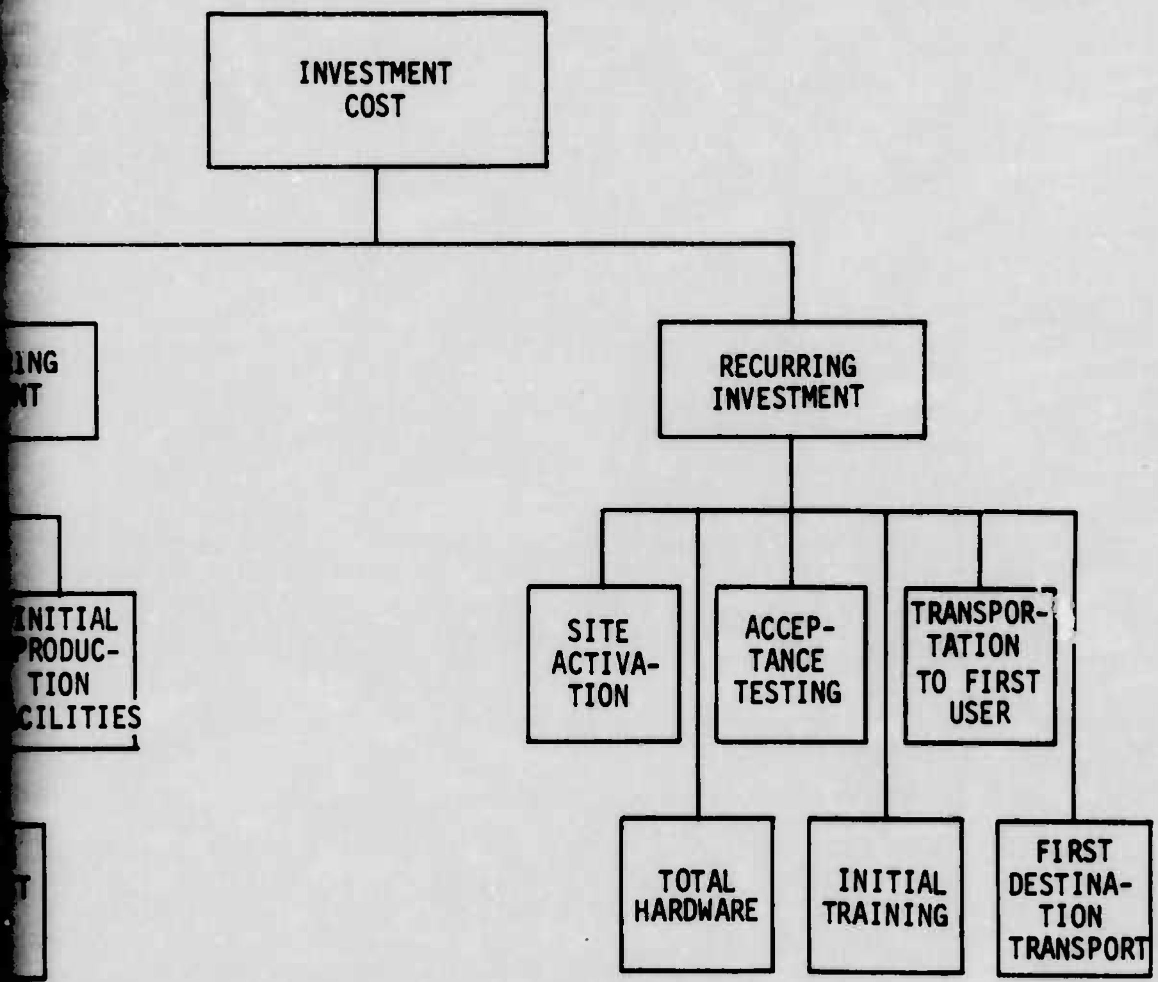


FIGURE B-2 Investment Cost Breakdown

1.3 OPERATION AND MAINTENANCE COST

Included in this category are the costs of personnel and material facilities, plus other direct and indirect costs required to operate, maintain, and support the equipment/system during the operational phase. Included also is the cost of all parts consumed in maintaining the equipment, as well as the cost of operating the necessary supply systems for parts, components, equipment, and information.

Costs are to be estimated on a per-year basis (in all categories). For the purpose of cost estimation, operation and maintenance (O&M) costs must be divided into certain elements specifically chosen to permit maximum use of the cost data presently available as inputs to this costing effort. These cost elements are presented in Figure B-4.

Figure B-4 is located at the end of this subsection (page B-18). The reader is asked to fold out this figure to conveniently see the relationships between the O&M cost elements as he reads the details in the succeeding paragraphs. The equation used to estimate O&M cost is as follows:

Annual O&M Cost = Equipment O&M
+ Vehicle O&M
+ Generator O&M
+ Air Conditioner O&M
+ Contractor Maintenance
+ Transportation Services
+ Indirect Operating Costs.

The individual elements of annual O&M cost, as indicated above, are calculated using the following formula:

Equipment O&M Cost = Pay and Allowances for Operators + Pay and Allowances for Maintenance Personnel + Replacement Training + Repair Parts + Integrated Logistical Support + Depot Rebuild

where

- Pay and Allowances for Operators = Number of Shifts x Number of Operators per Shift x Annual Pay and Allowances (source: Reference 4);

- Pay and Allowances for Maintenance Personnel = Cost per Active Maintenance Manhour x Total Maintenance Manhour per Equipment (source: Reference 4);

- Replacement Training Cost = Annual Turnover Rate x Cost of Training x Number of Operators Required (source: Reference 4);

- Repair Parts Cost = X Percent x Hardware Unit Cost (source: Reference 4)*;
- Depot Rebuild Cost = 0.809 (Depot Overhaul Rate**) x (Hardware Unit Cost)$^{0.881}$ (source: Reference 4);
- Integrated Logistical Support Cost = Inventory Maintenance + Holding Inventory + Transportation Charges to Overhaul;
- Inventory Maintenance Cost = Amount from Table B-2 (source: Reference 4);
- Inventory Holding Cost = 17 Percent*** x Initial Spares (source: Reference 4);
- Transportation Charges to Overhaul = 5 Percent x Spare Parts Cost (source: Reference 4);
- Vehicle Operation and Maintenance Cost = POL + $\frac{\text{Depot Overhaul}}{12}$ + Maintenance Personnel + (Repair Parts Factor + Replenishment Provisioning Factor) x Hardware Unit Cost + Second Destination Repair Parts Factor x Hardware Unit Cost (Table B-3, as taken from U.S. Army Tank-Automotive Command);
- Generator Operation and Maintenance Cost = MPA + Overhaul + Fuel, Lub, Oil + Parts (Table B-4, as taken from Reference 4);
- Air Conditioner Operation and Maintenance Cost = Value from Table B-5 (in the absence of specific information) (source: Reference 4);
- Contractor Maintenance Support Cost = Number of Depots x Contractor Manyears/Depot x Contractor Manyear Salary x 1/(Total Build) x 1/(Number of Years in Inventory);
- Transportation Services Cost = (2.52 Tons/Person/Year) x (Cost/Ton) x (Number of O&M Repairmen/Equipment) (source: Reference 29);

* Range of X used in past studies has been 5 to 20; specific value of X will be determined on the basis of the complexity of the equipment involved.

** If specific depot overhaul rate is not available, use 0.22.

*** The 17 percent shown is in accordance with the source referenced, but a new figure of 33 percent has been provided by ECOM. This new figure will be used on approval from AMC.

TABLE B-2
Inventory Maintenance Cost

Unit Dollar Value*	Total Line Item Cost** (Recurring)
Super High (over $25,000)	$720
High ($10,000 to $24,999)	$420
Medium ($2,500 to $9,999)	$130
Low (under $2,500)	$110
Average Cost***	$160

* Hardware line item cost
** Dollars, rounded
*** Weighted supply requirement cost per line item plus cataloging and provisioning costs.

TABLE B-3

Vehicle O&M Cost

(in FY 71 $)

Vehicle Description	Average Unit Cost	POL $/Mile	Depot Overhaul $/Vehicle	Maintenance Personnel $/Vehicle/Yr	Repair Parts Factor	Replenishment Provisioning Factor
Utility Truck, 1/4-ton (M151)	3,000	0.01	N/A	174	0.111	0.131
Utility Truck, 1/2-ton (M274A5)	4,760	0.01	2,380	174	0.103	0.113
Cargo Truck, 3/4-ton (M37B1)	4,230	0.02	3,530	271	0.087	0.131
Cargo Truck, 1-1/4-ton (M561)	18,370	0.01	5,690	248	0.066	0.103
Cargo Truck, 2-1/2-ton (M35A2)	8,790	0.02	4,420	245	0.090	0.131
Cargo Truck, 5-ton (M54A2)	26,040	0.04	8,550	164	0.119	0.106
Tractor Truck, 10-ton (M123A16)	54,290	0.05	12,110	164	0.088	0.145
Tractor Truck, 25-ton (M523)	45,274	0.07	12,200	164	0.088	0.145
Cargo Truck, 5-ton (M656)	48,440	0.04	11,140	155	0.087	0.106
Tractor Truck, 22-1/2-ton (SM746)	72,234	0.07	18,530	158	0.064	0.145
Cargo Truck, 1/4-ton (XM705)	7,750	0.02	3,600	140	0.066	0.103
Cargo High Mobility Vehicle, 8-ton (M520)	102,150	0.03	18,390	180	0.064	0.08
Tracked Cargo Carrier (M116)	43,800	0.07	18,000	325	0.05	0.122

Notes for Transportation Costs

	1st Destination	2nd Destination: CONUS	2nd Destination: Europe	2nd Destination: Far East
Repair Parts Factor	0.0056	0.0048	0.0060	0.0080

TABLE B-4
Generator O&M Cost

Size (kW) (60 Hz)	MPA ($)	Overhaul ($)	POL ($)	Parts ($)
1.5	90	375	130	215
3	90	645	230	215
5	90	695	360	210
10	60	550	400	140
15	75	435	460	165

TABLE B-5
Air Conditioner O&M Cost

Unit Capacity	Military, 60 Hz	Military, 400 Hz
6,000 BTU	$1,200	$1,400
9,000 BTU	$1,200	$1,250
18,000 BTU	$1,500	$2,400
36,000 BTU	$1,250	$1,400
60,000 BTU	$2,800	$2,500

- Indirect Operating Cost = (Cost/Man/Year) x (Number of O&M Repairmen/Equipment) (source: Reference 16) according to:

  <u>Cost/Man/Year</u>

  $780/man/year when stationed in CONUS
  $1,480/man/year when stationed overseas
  $1,000/man/year when location is indeterminate.

  Number of men is sum of O&M personnel required per year. If direct O&M costs are calculated separately, this cost can be established and listed separately also.

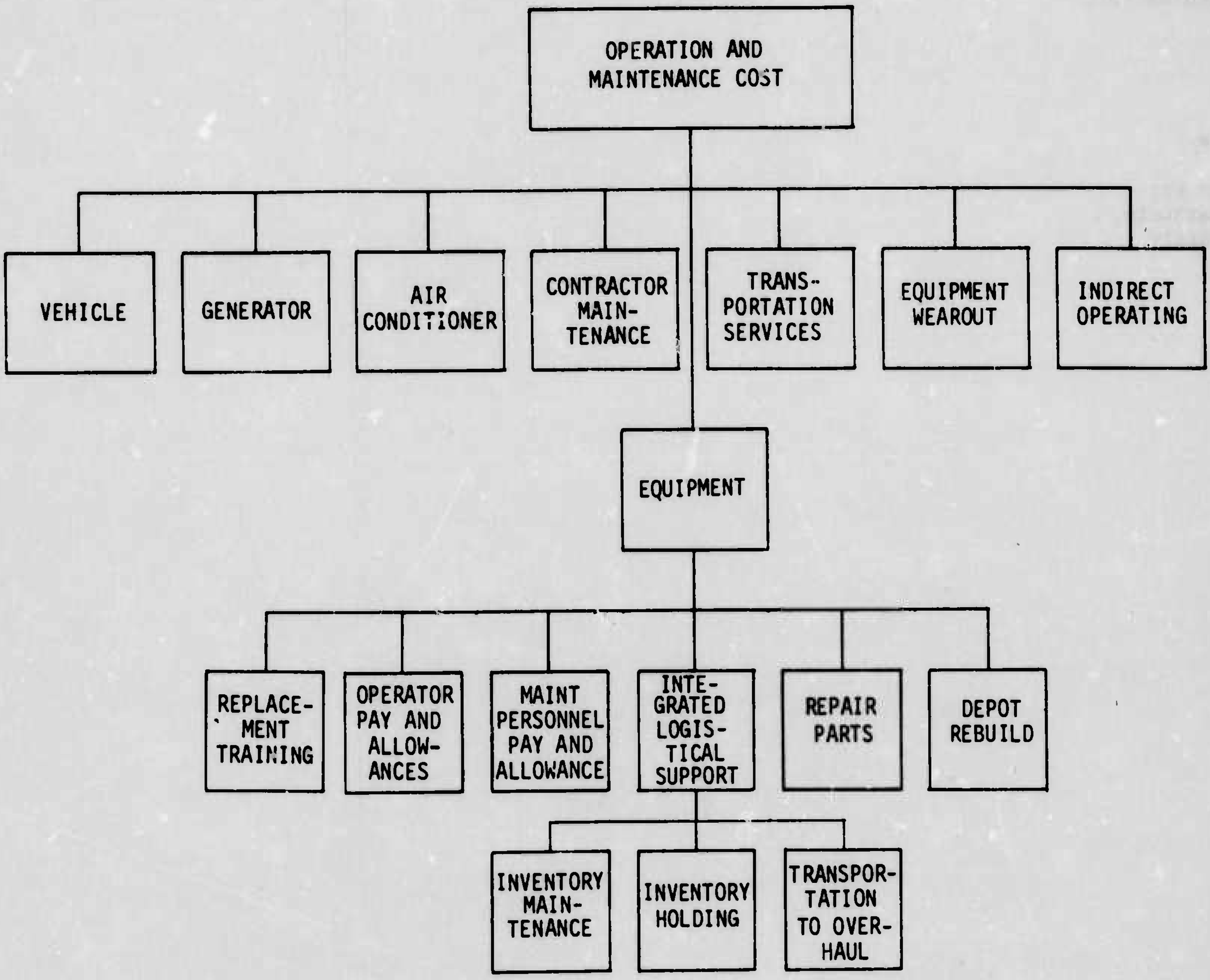


FIGURE B-4 Operation and Maintenance Cost Breakdown

2.0 TIME-ALLOCATION COST MODEL

In the time-allocation cost model, costs will be calculated for each fiscal year by aggregating the cost elements developed in determining life-cycle cost. The following is a list of time-allocation cost model outputs required for budgetary purposes:

- Test and evaluation costs
- Training costs
- Equipment procurement costs
- Research and development costs
- Manpower costs
- Operating costs
- Logistical support costs.

Each of these outputs is an aggregation of certain life-cycle cost elements, as shown in the following equations:

- $$TE = \sum_{j=1}^{N} (CDT_j + CTS_j + DTSA_j + GT_j) + \sum_{j=1}^{N} (PATE_j + OTE_j + ITSA_j)$$

where

TE = total test and evaluation costs (in dollars)

j = discrete type of equipment ($j=1, 2, 3, 3, \ldots N$)

CDT_j = contractor development tests for equipment type j

CTS_j = contractor test support for equipment type j

$DTSA_j$ = development test site activation for equipment type j

GT_j = Government tests for equipment type j

$PATE_j$ = production acceptance test and evaluation for equipment type j

OTE_j = operational test and evaluation for equipment type j

$ITSA_j$ = production test site activation for equipment type j;

- $$TR = \sum_{j=1}^{N} IT_j + \sum_{k=1}^{M} RT_k$$

where

TR = total training costs

IT_j = initial training costs for equipment type j

RT_k = recurring training costs for organizational set k

k = set of identical organizations (k=1, 2, 3, 3, ... M);

• $$PR = \sum_{j=1}^{N} (RI_j + ONR_j)$$

where

PR = total equipment procurement costs

RI_j = recurring investment costs for equipment type j

ONR_j = nonrecurring investment costs for equipment type j (excluding initial training and test and evaluation);

• $$RD = \sum_{j=1}^{N} ORD_j$$

where

RD = total research and development costs

ORD_j = research and development costs for equipment type j (excluding test and evaluation);

• $$MPWR = \sum_{k=1}^{M} PER_k$$

where

$MPWR$ = total manpower costs

PER_k = personnel costs for organizational set k;

• $$OPC = \sum_{j=1}^{N} O_j + \sum_{k=1}^{M} O_k$$

where

OPC = total operations cost (excluding personnel)

O_j = operating costs associated with equipment type j

O_k = operating costs for organizational set k;

• $$LSC = \sum_{j=1}^{N} LS_j + \sum_{k=1}^{M} LS_k$$

where

LSC = total logistical support costs (less personnel and replacement training)

LS_j = logistical support costs associated with equipment type j

LS_k = logistical support costs associated with organizational set k.

Each of the component elements on the right-hand side of the foregoing equations will be estimated in a manner similar to that in which they were estimated in life-cycle costing; CERs, cost factors, and bidder estimates will all be used. The implementation and support plans, however, will be more detailed than the candidate system descriptions of Task V. When this greater level of detail will produce more accurate estimates or is necessary to produce estimates for lower-level budget activities, a more detailed estimating procedure should be used.

3.0 COST ELEMENT DEFINITIONS

3.1 RESEARCH AND DEVELOPMENT COSTS

Research and development costs refer to all costs associated with the research, development, test, and evaluation of the system/equipment. Specifically, this covers concept initiation, validation, and full-scale development phases of the program, and includes costs for:

- Feasibility studies
- Engineering design, development, fabrication, assembly, and test of engineering prototype models
- Initial system evaluation
- Associated documentation.

The costs incurred in this category terminate with the satisfactory completion of the Government's operational test and evaluation (OTE) program.

3.1.1 Advanced Development

3.1.1.1 Contractor Costs

The cost of any concept initiation and validation work performed under contract is considered in this element.

3.1.1.2 Government Costs

The cost of any concept initiation and validation work performed by the Government is considered in this element.

3.1.2 Engineering Development

This element covers the costs of full-scale development associated with the equipment. It is in this portion of the R&D phase that a design concept, having been proven in theory, is engineered, fabricated, and tested. It typically includes program management, engineering, fabrication, testing, and associated documentation.

3.1.2.1 Contractor Costs

3.1.2.1.1 Program Management

This element refers to the technical and administrative planning, organizing, directing, coordinating, controlling, and approving actions designed to accomplish overall program objectives during the R&D phase of the equipment life cycle. Examples of these activities are configuration management, cost/schedule management, data management, contract management, liaison, value engineering, quality assurance, and integrated logistical support management.

3.1.2.1.2 Engineering

This element includes costs incurred for the study, analysis, design, development, system integration, evaluation, and redesign of equipments. It further includes direct labor, materials, test equipment, indirect services, and other direct or indirect costs incurred during the engineering process. The development of computer software is included as well as the cost of computer time.

3.1.2.1.3 Fabrication

This element includes the cost of direct labor, materials, tooling, and overhead required to produce full-scale development models and equipment on a limited basis for testing and design verification purposes.

3.1.2.1.4 Contractor Development Tests (CDT)

These tests are generally conducted on one or more prototype full-scale development models at the contractor's facility, to demonstrate that design specifications related to performance, control, maintenance, safety, maintainability, reliability, and human factors are satisfied. This element includes the cost of direct labor, materials, overhead, and other direct charges required to perform CDT. It also includes the preparation of test standards, plans, and procedures.

3.1.2.1.5 Test Support

This element includes the cost incurred in support of Government testing (DT/IOTE). It includes the cost of site activation, consulting services, training, spare parts, maintenance, testing, and transportation of equipment and contractor test personnel to the test site.

3.1.2.1.6 Industrial Facilities

This element includes the costs of structures or other real property required during full-scale development. It further includes the cost of modification, modernization, and alteration of these facilities. All direct labor, materials, overhead, and other direct charges are included.

3.1.2.1.7 Producibility Engineering and Planning (PEP)

PEP consists of those planning and engineering tasks undertaken during the development phase to ensure the timely and economic producibility of a component/item prior to release for production. PEP tasks consist of the following type activities:

- Development of technical data package
- Design of special-purpose production equipment and tooling
- Computer modeling/simulation
- Engineering drawings
- Engineering, manufacturing, and quality-support information
- Dimensional and tolerance data
- Manufacturing assembly sequences
- Wiring diagrams
- Material and finishing information
- Inspection, test, and evaluation requirements
- Calibration information and quality control data.

All other documentation is contained in the next subsection.

3.1.2.1.8 Documentation

This element includes the cost of preparation, revision, and reproduction of drawings, specifications, parts lists, plans, procedures, draft technical manuals/orders, and other documentation produced in support of project management, engineering fabrication, and testing functions. This cost element excludes computer software.

3.1.2.1.9 General and Administrative Costs

G&A includes the expenses of a contractor's general and executive offices; staff services, such as legal, accounting, public relations, financial, and similar activities; and other miscellanrous needs related to the overall business. Included are directors' and executive committee members' fees, bonuses, and incentive awards; employee stock options; and employee fringe benefits.

3.1.2.1.10 Fee

Fee is that portion of the total contract price that is allowed a contractor over and above the cost to produce or perform.

3.1.2.1.11 Other

This element includes all costs incurred by the contractor during full-scale development that are not included in the above-listed elements.

3.1.2.2 Government Costs

3.1.2.2.1 Program Management/Support

This element refers to technical and administrative planning, organizing, directing, coordinating, controlling, and approving actions designed to accomplish overall program objectives during the R&D phase of the equipment life cycle. Examples of these activities are configuration management, cost/schedule management, data management, contract management, liaison, value engineering, quality assurance, and integrated logistical support management.

3.1.2.2.2 Test Site Activation

This element refers to the costs incurred to prepare a test site for Government testing. It includes the cost of transportation of equipment and testing personnel to the test site. The cost of direct labor, materials, overhead, and other direct charges is also included.

3.1.2.2.3 Government Tests (DTE/IOTE)

The development test and evaluation (DTE) is designed to determine and/or verify technical performance and safety characteristics of an item, associated tools, and test equipment. It includes determination of structural, mechanical, electrical, chemical, and other physical properties of the equipment. Initial operational test and evaluation (IOTE) is that portion of operational test and evaluation performed during the FSD phase prior to a production decision. The objectives are to provide information at the production decision point as to the system/equipment military use, expected operational effectiveness, and operational suitability. This cost element includes the cost of direct labor, materials, overhead, and other direct charges incurred in the conduct of DTE/IOTE. It also includes any Government costs incurred in preparation of test requirements, plans, and procedures.

3.1.2.2.4 Government-Furnished Equipment (GFE)

This is the effective cost to the Government of GFE supplied to the contractor during the full-scale development phase of the equipment

life cycle. Equipment loaned to a contractor and later returned to the Government in good condition may result in zero cost for this element.

3.1.2.2.5 Other

This element includes the costs incurred by the Government during full-scale development not covered in the above elements.

3.2 INVESTMENT COSTS

Initial investment costs are one-time outlays (both recurring and non-recurring) other than those to produce and deploy an operational system. Included are the costs of establishing the logistical system, tooling and test equipment, engineering and management support, and acceptance testing.

3.2.1 Nonrecurring Investment Costs

3.2.1.1 Inventory Introduction

This element includes those costs associated with the introduction of items into the inventory system. They include costs of identification and description documentation, maintenance and supply cataloging, development of inventory and replacement rates, and development of rebuild, requisition, and procurement directives.

3.2.1.2 Initial Provisioning (Spares and Repair Parts)

This element includes components, assemblies, and parts to be procured as initial stock for maintenance replacement purposes, which may be identifiable line items in the procurement contract that provides an initial supply of repair parts to fill the planned pipeline.

3.2.1.3 First Destination Transportation

This element includes the cost for transportation of materials, parts, and components from the point of procurement, production, or testing to the first destination under contract from final assembly or test plant. Cost of packing is included.

3.2.1.4 Initial Tooling/Test Equipment

Tooling includes the planning, engineering, design, fabrication, assembly, and installation of tools (including modification and rework of tools for production purposes), assembly of tools, dies, templates, patterns, form blocks, manufacturing jigs, fixtures, master forms, gauges, handling equipment, load bars, work platforms (including installation of utilities thereon), and test equipment (such as checkers and analyzers) to support the manufacture of specified equipment.

It also includes maintaining tool records, establishing make-or-buy plans and manufacturing plans on nonrecurring tools and equipment, scheduling and controlling all tool orders, and programming and preparing tapes for numerically-controlled machine parts. Nonrecurring tooling includes the initial set of tools and duplicate tools necessary to reach rate production.

3.2.1.5 Instructor Training

Nonrecurring training involves only the training of service instructor personnel for a specific system, and is usually conducted by the contractor. It includes the cost of all devices, supplies, and services required in the performance of such training.

3.2.1.6 Initial Production Facilities

This element provides for system management production engineering prior to quantity procurement, to facilitate the manufacture of the procured item. It includes the establishment and operation of pilot production lines; the development of production data packages, engineering drawings, bills of materials, other production data, and factory layouts; the analysis of existing specifications and standards; and the proposal and institution of other studies or measures that will represent significant production advances and cost reductions. It also includes the engineering effort required to study the availability and suitability of commercial items for military use prior to quantity procurement. It does not include engineering conducted for development of tools and test equipment.

3.2.2 Recurring Investment Costs

This category contains cost elements that result from the size of the production buy or repeat order for the production of a communications system or its components.

3.2.2.1 Total Hardware

Total hardware costs include all the equipment built and required to operate the communications system. Included in this element are all the individual costs of equipments, vehicles, power sources, peripheral equipment, and crypto devices that are integral to the communications system. Escalation factors have been applied to the cost numbers to adjust the prices in terms of current dollars. All contractor investment costs for startup, tooling, test equipment, engineering/management, etc., have been included and amortized over the production quantity.

3.2.2.2 Initial Training

This element includes the training conducted by contractors, training centers, service schools, and mobile training teams for the initial crews and direct maintenance personnel required to introduce a system into the inventory.

3.2.2.3 Site Activation

This element will include all real estate acquisition, site preparation, fabrication of facilities, and installation of equipment required for the operation of the specified system. In includes administration, inspection, and supervision of construction and installation for all operational equipment, facilities, utilities, and ground improvements.

3.2.2.4 Transportation

These costs are associated with the shipment of each equipment and repair part of the initial provisioning supply from a major supply area.

3.3 OPERATION AND MAINTENANCE COSTS

Operation and maintenance costs are the costs of personnel, materiel facilities, and other direct and indirect costs required to operate, maintain, and support the equipment/system during the operational phase. It includes the cost of all parts consumed in maintaining the equipment, as well as the costs of maintaining the necessary supply systems for parts, components, equipment, and information.

3.3.1 Equipment Operation and Maintenance Costs

This element contains the cost of operating and maintaining the basic equipment after deployment. Included are the cost of crews, repair parts, logistical support, power consumption, and overhaul. Operation and support costs associated with ancillary and support equipment are not included in this element.

3.3.1.1 Pay and Allowances for Operators

This element includes pay and allowances for the operating crew members. The crew consists of those assigned as a primary duty to the direct operation of the communications system.

3.3.1.2 Pay and Allowances for Maintenance Personnel

This element includes the costs associated with direct maintenance labor at the organizational, direct support, general support, and depot levels of maintenance. Direct labor maintenance personnel are those military and civilian personnel engaged in the active repair and preventive maintenance function. Maintenance includes inspection, adjustment, tuning, alignment, cleaning, tool and equipment preparation, fault location, repair parts replacement, rebuild and overhual, modifications, recalibration, and final testing. Cost includes allowances and replacement training.

3.3.1.3 Replacement Training

This element includes those costs of training an individual to qualify as a crew member or maintenance person to replace, as needed, personnel previously trained for these positions.

3.3.1.4 Repair Parts

This element covers the cost of procuring new repairable parts that have been lost to the supply system, and nonrepairable parts and special tools consumed at organizational and DS/GS levels of maintenance during the repair of the equipment/system.

3.3.1.5 Integrated Logistical Support

This element includes costs required to maintain the inventory management of all major and minor items of supply for a communications system. It includes the commodity command organization elements concerned with the development and analysis of requirements and supply status data; preparation of materiel planning and supply control studies; and determination of the necessity for and the initiation of directive or authorizing action for cataloging, procurement, rebuild, distribution, or disposal. Costs of line-item receipt, storage, and issue at all levels are included in this element. In those cases where more than one system benefits from common use of line-item management, costs should be prorated among the supported systems.

Integrated logistical support cost will be estimated as the sum for inventory maintenance, holding inventory, and transportation charges. Inventory maintenance includes all recurring costs for identification and description documentation; maintenance and supply cataloging; development of inventory and replacement costs; development of rebuild requisition; and procurement directives. Holding inventory is the cost of holding inventory in the supply system for one year, which involves the measurement of resources expended in storage, inventory adjustment, interest, and obsolescence. Transportation charges are those costs associated with the shipment of each line item from a major supply area.

3.3.1.6 Depot Overhaul

This element covers the in-house costs associated with equipment overhaul estimated as an annual cost for each fielded equipment. This includes labor and materials cost, and also a cost for transporting equipment to the depot and returning it to operational status.

3.3.2 Vehicle Operation and Maintenance Costs

This element contains the cost of operating and maintaining support vehicles required as an integral part of the communications equipment. Included is POL consumption, repair parts, replenishment provisioning, depot overhaul, and maintenance personnel costs. The driver or operator is considered to be part of the basic operator costs.

3.3.3 Generator Operation and Maintenance Costs

This element contains the operation and maintenance costs for engine generators and other equipments used to provide power for the tactical communications system. Costs included are overhaul, POL, repair parts, maintenance manpower, and MPA. Operator personnel costs are included in the crew cost of the basic equipment.

3.3.4 Air Conditioner Operation and Maintenance Costs

This element contains the operation and maintenance costs for air conditioners common to tactical communications applications. Costs include repair parts and maintenance labor only. The operating manpower costs are included in the basic equipment crew costs, and the electric power consumed is included in the generator operating cost.

3.3.5 Contractor Maintenance Support Costs

This element includes the annual cost of contractor-performed maintenance to support a communications system in the field for one year.

3.3.6 Transportation Services Costs

This element includes the transportation of support tonnage required per individual per year.

3.3.7 Equipment Wearout

This element includes the replacement of equipments for the life expectancy of the unit. Equipment that must be replaced due to wearout beyond repair, enemy action, abandonment, pilferage, and other causes is included in this element of cost.

3.3.8 Indirect Operating Costs

This element is the prorated share of the cost of medical care, service-wide supply and logistics, higher-command headquarters operation not otherwise accounted for, transportation, and other miscellaneous support costs.

APPENDIX C
COST METHODOLOGY LITERATURE

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COST METHODOLOGY LITERATURE

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APPENDIX D
NETWORK SIMULATION AND ANALYSIS MODELS

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NETWORK SIMULATION AND ANALYSIS MODELS

1.0 INTRODUCTION

The major purpose of a network model is to aid in quantitative evaluation of network alternatives. It accomplishes this objective by providing the analyst with a quantitative measure of the system's behavior.

The following models will be used in the INTACS evaluation:

- CASE
- SIMCE
- Interference Prediction Model (IPM).

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2.0 CASE

The Communications Analysis, Simulation, and Evaluation (CASE) model is a modular package of 41 programs. CASE simulates a communications system by synthesizing input data and employing an event-by-event simulation process. More specifically, CASE consists of three principal parts:

- The preprocessor, which organizes and formats the input data;
- The simulator, which processes messages through the sized system and records the response of the system;
- The postprocessor, which summarizes the data recorded by the simulator and provides certain statistical output.

CASE allocates channels among three modes (telephone, teletype, and data), but simulates only TP and TTY. Separate simulation runs are required for TP and TTY; competition between the two modes is not considered. Sole user circuits are allocated for data, but transmission of data is not simulated by CASE.

COMSR input to CASE identifies field units, their locations, and their traffic requirements. TP and TTY traffic requirements indicate the unit-to-unit message rates that are used to determine the frequency of message generation for the call-by-call simulation.

At the beginning of the simulation run, the network is empty. The estimated transient time is ten minutes of simulation; then stability exists and simulation output is pertinent. Manual inputs include nodal connectivity, nodal location, and channel requirements (the latter two are provided by SIMCE). Other manual inputs are as follows:

- Nodal equipment characteristics
- Communications personnel handling times
- Switchboard parameters
- Patching thresholds
- Node identification (area or command).

CASE addresses patching, and does not allow patching through command nodes.

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Traffic routing is determined by the transshipment algorithm (a multicommodity/minimum-cost algorithm), unless least-cost routing is specified. Rerouting is done by the least-cost algorithm, which requires manual input indicating the cost of message flow over each link.

2.1 APPLICABILITY TO SYSTEM EFFECTIVENESS EVALUATION

CASE provides two important measures of system effectiveness: grade of service (GOS) and speed of service (SOS). GOS is computed for TP traffic by counting the number of blocked calls during the call-by-call simulation.

2.1.1 Computation of GOS

For TP traffic, GOS is calculated as the probability that a message is not blocked. Blockage occurs in any of the following instances:

- An operator or plug is not available at one of the nodes along the route;
- A link channel is not available;
- A loop channel is not available between the node of destination and the unit of destination;
- The telephone is busy at the unit of destination.

CASE permits rerouting in the event of blockage at a node. In this instance, blockage occurs (for system GOS) only if all reroutes fail. GOS is computed for the system, individual nodes, links, and unit-to-unit.

TTY messages are not blocked, but remain in queue until a connection is successfully established for transmission. Therefore, upon termination of the simulation phase of the model, a number of TTY messages may still remain in queue. System GOS is actually the message completion rate, calculated by dividing the total number of messages completed by the total number of messages generated. The message completion rate is also provided for nodes and units that originate TTY traffic.

2.1.2 Computation of SOS

CASE measures TP delay time by considering the following contributing factors:

- Queueing time at nodes (dependent upon operator and plug availability);
- Time required by an operator to make a switchboard connection.

Precedence levels and preemption for TP messages are not handled by CASE.

CASE measures TTY delay time by considering the following factors:

- Queueing time at nodes (dependent upon communications center personnel availability);
- Communications personnel handling time (message center clerk, transmitting and receiving operators);
- Message tape perforation time;
- Transmission time.

Precedence levels and preemption for TTY messages are handled by CASE. CASE determines the priority of a message in the following manner:

- The percentage of messages of each precedence level are input to CASE (for example, it may be determined that 10 percent of all TTY messages generated by the system are flash, 15 percent immediate, etc.);
- When a message is generated, for any needline, during the simulation, a precedence level is randomly assigned, based on the input percentages for the entire system.

2.1.3 Fading Model

CASE includes several programs whose purpose is to simulate atmospheric fading. Inputs to the atmospheric fading model include transmission mode, equipment operational parameters, frequency, and distance between terminals. The model generates a signal-to-noise ratio by time interval throughout the simulation run. For voice messages, this S/N ratio is compared to a go/no-go threshold, indicating whether or not the circuit is adequate. For messages transmitted as pulses or bits, the S/N ratio yields a bit error rate that indicates whether or not the transmission is considered a failure.

2.2 SUMMARY

Despite its attention to a large number of system characteristics, CASE has several features that are unrealistic and limit its applicability to the effectiveness methodology. For example, the need for security in transmitting messages is not addressed in CASE; no means of identifying equipment capable of transmitting securely exists. No special queue exists for secure messages awaiting the availability of a secure transmission capability.

In addition, CASE does not consider the following:

- Data transmission simulation
- Precedence levels for TP
- Preemption for TP
- Terrain.

The CASE model simulates Army tactical communications while allocating channels to TP, TTY, and data. The main values of CASE to the INTACS team are its measurement of GOS, SOS, and atmospheric fading.

3.0 SIMCE

Simulation - Communications-Electronics (SIMCE) is a computer simulation model constructed to aid in the design and evaluation of communications systems. It accomplishes this task by synthesizing the traffic demands imposed on the system, by sizing the communications links, and by providing a measure of system effectiveness.

SIMCE begins by converting user communication requirements to erlang traffic flow between typical units; the model then assigns specific units to nodes. Connectivity between specific units is, in part, determined by the command/support relationship between the units. SIMCE then computes nodal needline traffic volume. This information is combined with the routing scheme to determine the volume of traffic over each link of the network.

3.1 APPLICATION TO SYSTEM EFFECTIVENESS EVALUATION

Within certain limitations (which will be noted later), the current version of SIMCE seems to have three primary uses to the INTACS concept evaluation program:

- Given unit locations and needlines and approximate area nodal locations, SIMCE can connect units to nodes and provide recommended nodal locations for the area system.
- Given traffic requirements and desired GOS for area and command systems, SIMCE will provide channel requirements for each link.
- Given traffic requirements and link capacities, SIMCE will provide link GOS.

The COMSR data base includes approximately 4170 specific units and 580 typical units. SIMCE can handle 3200 specific units and 420 typical units. This apparent difficulty poses no problem, since SIMCE must be run separately for area/command systems and for Theater Army/Corps and below.

3.1.1 Nodal Relocation

The COMSR-provided specific unit deck gives the location of each specific unit with interunit traffic requirements. This location is expressed in terms of X-Y coordinates (in six digits), and is the actual location of the unit with respect to an arbitrarily established set of axes.

Task V personnel will provide, as input to SIMCE, the approximate location of each node in the area nodal network. SIMCE assigns each specific unit to the nearest node. Based on unit traffic requirements and distance from node, the model can relocate the nodes through an iterative process of minimizing total unit-to-node erlang kilometers. The process ceases when the average nodal movement is below 0.001 kilometer.

This nodal-relocation feature has just recently been added to the model, and has not been used in any previous study. It does not take terrain into consideration. It is to be used for relocating nodes in an area network only, and does not consider any interrelationships with the command nodal network.

3.1.2 Channel Requirements/GOS

The COMSR data base indicates message requirement by communications mode (voice, teletype, data, fax, video), precedence (routine, priority, immediate, flash, flash override, realtime), security classification (unclassified, FOUO, confidential, secret, top secret), frequency (number of messages per 24 hours and peak hour percentage), and message length. SIMCE currently considers voice, teletype, and data messages, and categorizes them as urgent (flash and above) or routine, and as secure or nonsecure. Message frequencies are calculated for the 8 busiest hours of the day, and are categorized as constant (24 to 96 messages), frequent (8 to 23), daily (1 to 7), or infrequent (<1). SIMCE assigns a particular value for each of these categories (constant 60, frequent 16, daily 4, infrequent 0.5); however, the model is being modified to accept any value for each category. Message length is constant throughout any run of the model, but SIMCE will accept any value for TP holding time and any value for TTY holding time.

If a requirement is both urgent and constant, a sole user circuit is assigned; otherwise, the traffic will compete on a common user circuit. The model then considers ten circuit types:

- TP, sole user, secure
- TP, sole user, nonsecure
- TP, common user, secure
- TP, common user, nonsecure
- TTY, sole user
- TTY, common user
- Data, sole user, secure
- Data, sole user, nonsecure
- Data, common user, secure
- Data, common user, nonsecure.

All TTY circuits are considered to be secure.

The internodal traffic routing scheme must be provided manually. SIMCE requires that all traffic between a pair of nodes must follow the same path (i.e., no routing mixes or alternate routing). Typically, the routing scheme might specify that traffic must be routed through the minimum number of nodes, and when more than one minimum path exists, traffic must be routed on the most direct path away from FEBA.

Given unit and nodal locations, traffic requirements, and a routing scheme, SIMCE can:

- Accept channel requirements as input and provide GOS as output;
- Accept design GOS as input and provide channel requirements per link as output.

SIMCE calculates GOS for TTY, TP, and data. The number of messages of each mode is first converted to an erlang traffic loading. The traffic and the link capacities are then input to a mathematical formula to determine GOS.

With link capacities as input, SIMCE calculates GOS by any of three mathematical formulas. Use of a particular formula depends upon the assumption concerning what happens to a call should it be blocked. The Erlang B formula will be used in INTACS; this formula assumes that calls are dropped when blockage occurs.

When design GOS is input, channel requirements are calculated in a similar manner. No simulation is actually performed by the model. In either event, four separate runs are required for each concept. SIMCE considers the command network separately from the area network, and considers the Theater Army separately from Corps and below. This latter factor introduces an additional burden of providing dummy access points to represent the sources/sinks for traffic that crosses the boundary of TA/Corps.

SIMCE does not consider:

- Equipment characteristics
- Switching
- Preemption
- Alternate routing
- Alternate modes
- Routing mixes
- Operational environment
- Terrain.

3.2 SUMMARY

Despite the fact that SIMCE fails to incorporate some significant features of tactical communications systems, it will be an important tool in sizing communications systems and in analyzing system effectiveness. SIMCE will provide the INTACS team with refined nodal locations, link GOS, and channel requirements for each link in the network.

4.0 INTERFERENCE PREDICTION MODEL

Electromagnetic compatibility analysis of an INTACS concept requires the use of the Control Data Corporation 6500 computer at Fort Huachuca, Arizona, to perform the many repetitive calculations required during the analysis and to process the large volume of data needed for the analysis. Use of a computer in performing such analyses requires the programming of a mathematical model. The interference prediction model (IPM) is derived from the equation for propagation path loss, which is the decrease in strength of a radio signal as it is transmitted from its point of origin in a transmitter to its destination at the intended receiver. Because this equation is equally applicable to undesired signals (whether from friendly transmitters or enemy jammers), it can be used to represent or model the typical radio interference situation. This basic model, however, cannot operate alone in the performance of analyses. A program to allow the use of the model on the computer must include other programs to arrange the input data and translate the outcome from machine language to numbers or words that can be understood and evaluated by the analyst. The IPM programs are designed and arranged to help the analyst predict how well INTACS materiel and concepts will perform their intended function when immersed in their intended operational environment. The computer programs that comprise the IPM can be separated into three major sections. These sections, together with the input and output data, are shown, in block diagram form, in Figure D-1.

Despite the speed and accuracy provided by a computer, its operation and output can only be as good as input data furnished. Block 1 in the diagram covers two types of input data. One type consists of files of reference data that describe equipment characteristics (such as transmitter power output, antenna spectrum signature data, general antenna data, types of modulation, etc.) that are modified only when measurement data indicate the need for revision. Other data are defined by the problem to be analyzed. First among these are the deployment data, which are derived from a test bed and consist of a list of equipments, transmitters, and receivers together with their locations, all defined by a specified tactical situation. Other data, which are defined neither by the equipment portrayed nor by the test bed, include propagation and terrain statistics (which contribute to the outcome of path loss calculations) and data which control the size of samples to be taken.

Block 2 (the first section of the IPM proper) carries out all preliminary data processing. In effect, it arranges all the work to be done in an order best suited to the assigned task. It establishes and checks the

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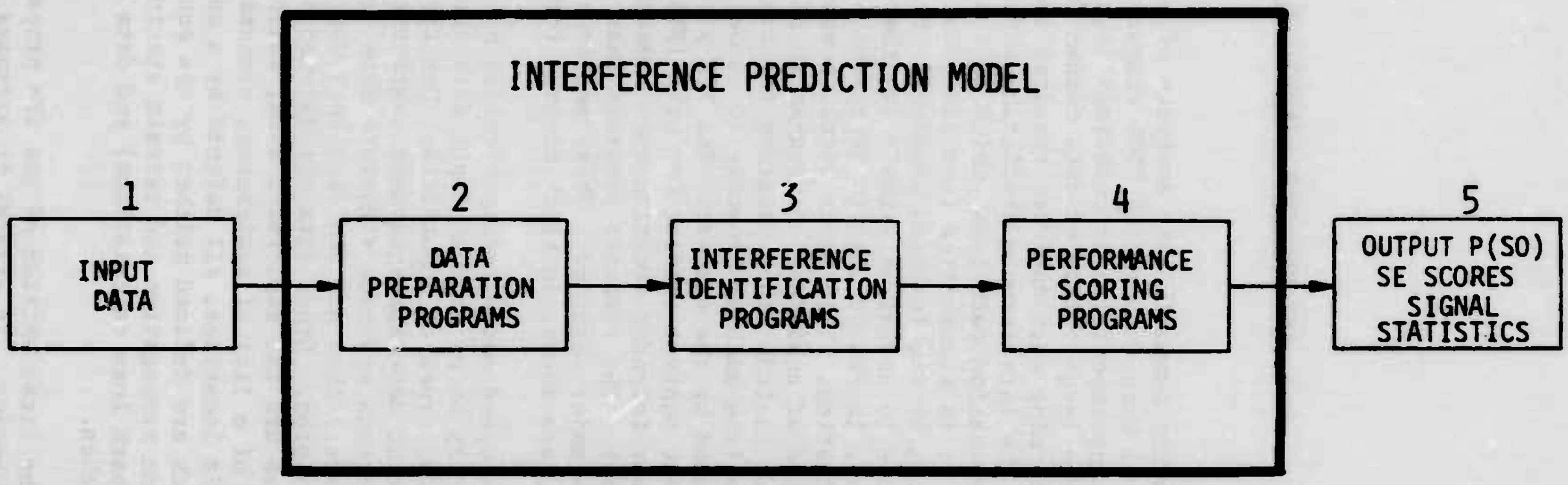

FIGURE D-1 Interference Prediction Model

test bed data, including the technical characteristics and geographical locations of all deployed CE equipments. These are sorted by frequency, geographical area, type of equipment, and organization, and by other groups specified by the experimental design. Information provided in the scenario or included in published doctrine is used to assign duty cycles and importance weights. Based on the accuracy or statistical confidence desired in the final determinations of system effectiveness or equipment performance, samples of large groups are selected.

Block 3 contains the interference identification programs, which calculate estimates of the levels and types of signals and interference at the RF input terminals of each receiver included in the previously selected sample. It is here that the fundamental model (the propagation path loss equation) is used. The equations used are designed to include antenna gain, output power, types of terrain, frequency, time of day, season, and year. Culling routines are used to prevent lengthy calculations for transmitters that can be determined to have signals at or below the receiver threshold. The variability of signal strength (i.e., its variance) is determined for each effective signal.

Block 4 represents programs designed to calculate several different types of performance scores. The scores calculated first are probability of satisfactory operation (P(SO)) for each of the sampled CE links (transmitter-receiver paths). These scores are based on the RF levels of desired and undesired signals at the input of each receiver, compared to performance thresholds (scoring data) defined for each possible receiver-transmitter-interferer combination. P(SO) scores are provided for the clear-channel situation (the communicability score), for the same channel with interferers considered (the compatibility score), and for each interferer (the conditional compatiblity score). If the interferer is a jammer and the receiver scored is its intended target, the compatibility score is a vulnerability score. These scores can be combined in weighted averages to determine the performance of whole classes of CE equipment into whatever grouping is desired for analysis purposes.

Block 5 shows the IPM output. This output can take several forms, depending on the type and detail of the analysis desired. If it is desired to investigate in detail all the factors involved in a small problem, a complete printout of all calculations made in the IPM can be provided. For large-scale deployments, however, the factors to be analyzed are selected beforehand (based on the objectives to be met), and the computer sorts the outcomes of various scoring actions, making weighted averages and consolidating the output so that the overall picture is visible to the analyst. Various statistics can be prepared to show the influence of factors such as path length, the presence of own forces, and effect of opposing forces' CE, or the success of enemy jamming.

4.1 BACKGROUND

The U.S. Army Electronic Proving Ground (USAEPG) has been tasked to plan an electromagnetic compatibility and vulnerability (EMC/EMV) analysis of baseline and other candidate communications-electronics concepts for Phase II (mid range time frame) of INTACS. Tasking was designated through the U.S. Army Materiel Command (AMC) and the U.S. Army Test and Evaluation Command (TECOM) under AR 11-13. Concurrently, the U.S. Army Communications-Electronics Computer Applications Agency, later absorbed as a part of the U.S. Army Management Systems Support Agency (USAMSSA), was tasked to develop test beds for EMC analysis of the baseline and candidate concepts.

4.2 TEST BEDS

The test beds are computer simulations of the CE environment created by an Army in the Field force model opposing appropriate enemy forces in Europe in the 1976 to 1986 time period. The force model is designed on the CONAF organizational concept, as modified by the Echelons Above Division (EAD) reorganization. The baseline test bed simulates the technical and geographic relationship among all electromagnetic emitting and receiving devices required to support friendly and enemy forces at the time described by an appropriate scenario. Such a test bed creates an operational environment which simulates the potential EMC/EMV conditions that could occur in a future combat environment.

The test bed is constructed and presented on a series of computer-derived magnetic tapes, listings, and other documentation. The technical characteristics; geographic coordinates; net, equipment, and operator names; and other appropriate computer processing numbers, codes, and identifiers are written into the principal tape -- the Deployment Data File. Individual emitter and receiver records are assembled on this tape in a predetermined sequence of friendly and enemy nets and equipment for ease in processing.

CE equipments are deployed in accordance with the organizational, doctrinal, and equipment concept for the baseline INTACS concept. Deployed CE equipments are given specific assignments of frequency, power output, antenna design, and netting structure. The same deployment of friendly and enemy forces is used for the preparation of the candidate CE concept simulations. Equipments, nets, or systems are added, deleted, or changed from the baseline test bed, in accordance with changes required by the candidate concepts.

4.3 FACTORS

Six factors are applied to refine the force model for use by the computer models. These factors are described as follows:

- Cull distance - Minimum and maximum cull distances are those distances within or beyond which radio communications are not required and should not be attempted;

- Link weight - A numerical factor that indicates the relative probability of the transmission of important traffic over that link with respect to all other links possible in that net;

- Net weight - A numerical factor that reflects the relative importance of a net type to the overall accomplishment of the force mission;

- Posture - A numerical value that reflects a unit's or net's relative degree of combat-related activity;

- Duty cycle - The percentage of time that some link in a net is on the air (i.e., that some transmitter is being used);

- Intelligence value - A numerical factor that ranks the nets in a force model simulation according to their projected intelligence value to the enemy.

4.4 PROGRAMS

The IPM is comprised of a series of computer programs designed to process a Deployment Data File (a simulated CE environment) to obtain a quantitative estimate of the communicability, compatibility, and vulnerability probabilities of CE links, nets, or systems in an operational environment.

This series of computer programs is organized into five principal sections:

- Preliminary data processing
- Link formation and selection
- Probability scoring
- Interference identification
- System effectiveness.

4.4.1 Preliminary Data Processing

Preliminary data processing is required to compare a new test bed with existing EMETF data files. The EMETF develops new data to update net and link weighting factors, equipment scoring data, and analysis design codes in accordance with any new organizational doctrine or equipment in the test bed. The factors delineated in paragraph 4.3 are updated on a new magnetic tape called a Military Values Master File. Equipment codes

are assigned to any new equipment and antenna types, and appropriate data are added to an equipment scoring matrix. Appropriate net, equipment, or other analysis category codes are assigned, based on the analysis plan. The codes facilitate presentation of the output of system effectiveness (SE) scores in the proper array for ease of evaluation and comparison.

The confidence level and the accuracy desired within the limits of analysis time constraints are also assigned at this time, to control the number of links to be sampled.

4.4.2 Link Formation and Selection

Within the design of the analysis, various elements of the environment can be selected for processing. This selection can be made by a major organization, division, or corps, or by an entire Army in the Field. Selection can also be made by frequency band (for example, only SHF troposcatter multichannel systems), various combinations of friendly and enemy CE and electronic warfare (EW) systems, or other categories of foreground and background environment.

All CE nets of interest in the test bed are reviewed in the process of link formation, and all links not eliminated by minimum or maximum cull distances and by a zero link weight are formed. The net weight, the posture factor, and the link weight of each link formed are multiplied by the computer. A link value for each link with respect to all other links formed is assigned. This value indicates both the relative importance of the link and also the probability that that link will be active in the environment at the time being simulated.

The links formed simulate the electromagnetic environment created by the tactical situation involved. This is a function of the relative importance of the net (net weight) to the mission of the force, as qualified by the relative combat activity in the unit being supported (posture factor) and the probability of a link being in use and carrying important traffic (link weight).

4.4.3 Link Sampling

Sufficient links are sampled (from among those formed) to obtain a final score that is within the confidence level and accuracy requirement desired. Links are assembled within various subgroups or cells. Typical cells are defined by such classifications as net, net type, or equipment class. The total number of links sampled is the aggregate of those required within all cells. Sampling within any cell is weighted by the link values. The link sample favors the most important links in the most important nets with the highest degree of combat activity. Thus, the links (transmitter and receiver) with the highest probability of being active are sampled most heavily, and the most realistic electromagnetic environment is created.

4.4.4 Interferer Identification

Each friendly and enemy emitter which has formed a link is a potential interferer. The duty cycle of the net in which each transmitter operates is divided among the individual transmitters according to link weighting; thus, the probability of simultaneous transmission is established. Each transmitter is entered in a potential interferer file for use in probability scoring.

4.4.5 Probability Scoring

Links are scored first in the absence of interference. The probability of successful operation (P(SO)), or probability of successful information transfer, is measured from operator to operator. Signals are modeled from the output of the transmitter, through the Longley-Rice irregular terrain propagation model (as modified for EMETF use) and the antenna models, to the receiver input. The resultant distributions of desired signals are combined with empirically-derived scoring data to obtain the P(SO) scores. These P(SO) scores are a direct reflection of the probability that the equipment characteristics, frequency, distance, and propagation conditions simulated will result in successful communications.

The degradation of this link communicability score is next measured by a calculation of degradation caused by unintentional interference and by intentional interference (jamming) by including a consideration of undesired signals. The discrete interfering equipments, both friendly and enemy, are identified by net, equipment type, and other categories of interest.

Interceptibility and the probability of successful direction-finding are also calculated between friendly transmitters and enemy EW receivers, both in the presence and the absence of background interference.

4.4.6 System Effectiveness

The P(SO) score of discrete CE links and the measured degradation of those links by an individual interferer can be used to obtain an indication of CE performance or vulnerability in the environment. Performance within a net, a net type, an equipment, an organization, or an entire CE system can be obtained from a weighted average of the P(SO) of the sampled links in a desired category. Such a weighted average is called the system effectiveness (SE) score. The SE score of a large number of links from a test bed (i.e., the entire test bed or a broad equipment classification) is less useful than the SE score derived by net type or net. Very large numbers of the links contain a mixture of equipment, frequency use, CE requirements, tactical dispositions, organizations, and functions. This mixture tends to obscure the performance of the CE system in a particular environmental condition created by the tactical situation. System effectiveness by net reveals the effectiveness of particular battalion command

nets in particular areas of the environment. SE by net reveals the EMC/EMV problems that can develop in discrete nets, and is most useful in the evaluation of competing CE systems.

SE scores are obtained for each net type in the INTACS baseline and candidate concepts. The scores are assembled by major organization (echelon) for ease in evaluation and comparison. SE scores are also obtained for each net (in a net type) that obtains a poor communicability or compatibility score, or that is vulnerable to jamming, intercept, or direction-finding. The P(SO) scores for the links within those nets that have poor performance or that are vulnerable assist in determining the cause of poor performance, the source of interference, and the cause of EW vulnerability. SE scores for multichannel systems are obtained by echelon, by net type, and by equipment type. The equipment type category is used to facilitate comparison between line-of-sight (LOS), troposcatter, down-the-hill radio relay, and satellite communications systems.

4.5 SUPPLEMENTARY ANALYSIS

The EMETF uses other analysis techniques in addition to P(SO) and SE scoring of selected nets and net types. A frequency and distance separation analysis can be performed on selected cosited, high-frequency, LOS, and troposcatter multichannel systems in the test bed. Consideration is given to potential harmonic and image frequency problems, as well as transmit/receive separation criteria. An assessment of the advantages and disadvantages of radio frequency requirements of competing concepts is made. A system performance analysis of adaptive systems, such as MARTS, is also performed.

APPENDIX E
SAMPLE COMMUNICATIONS SYSTEM EVALUATION

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SAMPLE COMMUNICATIONS SYSTEM EVALUATION

In the following examples, two fictitious communications systems (X and Y) are evaluated to demonstrate the use of the Task III effectiveness methodology. The analysis is in outline form, with only enough detail to convey the essence of the methodology. Wherever possible, the repetition necessary for extensive analysis has been omitted. For the sake of clarity, cost and risk are not considered.

1.0 ALLOCATION OF UTILITY

The criteria used for utility allocation was the value of improvement in the effectiveness of the present system. A total utility of 1000 utiles was selected for convenience. This utility was allocated among the areas, as presented in Table E-1. Next, the area utilities were subdivided into aspect utilities (Table E-2). Finally, each aspect was broken down into MOE utilities (Table E-3). A summary of the allocation is presented in Figure E-1. This is not intended to be the allocation used in Task V, but merely a vehicle to provide a quantitative example.

2.0 EVALUATION OF THE SYSTEMS

Once the allocation process is complete, each system must be evaluated to determine what portion of the available utility it will be awarded. The system under consideration is compared to the baseline system, and is assigned a utility value based on performance relative to the baseline, which has a utility of zero. Parameter values that fail to meet baseline requirements have a negative utility value. Parameter and baseline values for the examples are presented in Table E-4. Parameter values that correspond with maximum utility are shown in the same table. All parameters were reduced to a two-digit number, for convenience.

The evaluation process is illustrated in Figures E-2 and E-3. For the grade of service evaluation in Figure E-2, the utility-to-parameter relationship is nonlinear, so the utility value for each alternative is based on judgement. In fact, all parameters are essentially nonlinear; however, with some of these, a linear relationship may be judged a reasonable approximation. An example of this is weight, as shown in Figure E-3. For every unit of reduction in weight, the utility increases by 2 utiles. This type of relationship is obviously preferred, and will be used when

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TABLE E-1
Allocation of Utility to Areas

Area	Utility
Quality of Service	260
Mobility	100
Transportability	110
Vulnerability	90
Survivability	40
Flexibility	60
Reliability	70
Logistical Support	50
Security	90
Operability	20
Standardization	10
Maintainability	40
RF Spectrum Requirements	30
Electromagnetic Compatibility	30
	1000 utiles

TABLE E-2
Allocation of Utility to Aspects

Areas and Aspects	Utility
1. Quality of Service	
1.1 Grade of service	110
1.2 Speed of service	80
1.3 Information quality	70
2. Mobility	
2.1 Setup/teardown time	40
2.2 Communication during moves	60
3. Transportability	
3.1 Equipment size and weight	70
3.2 Vehicle requirements	20
3.3 Portability	20
4. Vulnerability	
4.1 Physical destruction	30
4.2 Susceptibility to direction-finding	60
5. Survivability	
5.1 Impact of node destruction	15
5.2 Impact of jamming	25
6. Flexibility	
6.1 Function in varying operational environments	15
6.2 Changes in force structure	6
6.3 Change of mission	5
6.4 Varying ratios of traffic	2
6.5 Impact of added subscribers	2
6.6 System modularity	5
6.7 Downtime for CP displacement	10
6.8 Operation in varying deployments	12
6.9 Hardware modularity	3
7. Reliability	
7.1 System availability	70

TABLE E-2
(continued)

Areas and Aspects	Utility
8. Logistical Support	
8.1 Required parts support	20
8.2 Power requirements	30
9. Security	
9.1 Provision for increased secure communications	4
9.2 Limitations due to increased security	3
9.3 Ratio of secure-to-nonsecure users	10
9.4 Interface security requirements	3
9.5 Restoration after compromise	15
9.6 Degree of security	30
9.7 Interceptibility	25
10. Operability	
10.1 Difficulty of system operation	10
10.2 Service features	10
11. Standardization	
11.1 Multiplicity of CE equipment	10
12. Maintainability	
12.1 Provision of preventive maintenance	15
12.2 Provision of corrective maintenance	20
12.3 Provision of software update	5
13. RF Spectrum Requirements	
13.1 RF bandwidth requirements	10
13.2 Flexibility of frequency allocation	20
14. Electromagnetic Compatibility	
14.1 INTACS compatibility	15
14.2 INTACS/other system compatibility	15
	1000 utiles

TABLE E-3
Allocation of Utility to MOEs

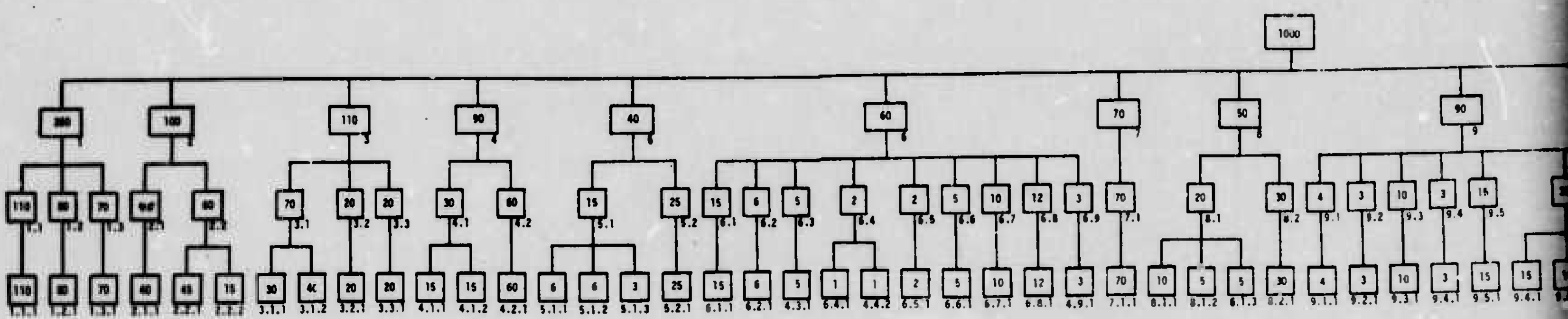
MOE		Utility
1.1.1	Grade of service	110
1.2.1	Speed of service	80
1.3.1	System communicability score	70
2.1.1	Physical setup/teardown time	40
2.2.1	Percent GOS reduction during a move	45
2.2.2	Information intelligibility	15
3.1.1	Volume of system	30
3.1.2	Weight of system	40
3.2.1	Percent transport vehicles organic	20
3.3.1	Portability*	20
4.1.1	FEBA centroid function	15
4.1.2	Susceptibility to destruction*	15
4.2.1	EMC/EMV direction-finding	60
5.1.1	Number of nodes destroyed to reduce GOS to specified level	6
5.1.2	Subscriber loss - node destruction	6
5.1.3	Alternate capabilities*	3
5.2.1	EMC/EMV jamming vulnerability	25
6.1.1	Operational environment*	15
6.2.1	Force structure*	6
6.3.1	Change in mission	5
6.4.1	Variation of data/voice traffic ratio	1
6.4.2	Data transmission*	1
6.5.1	Addition of subscribers*	2
6.6.1	System modularity*	5
6.7.1	Downtime for CP displacement	10
6.8.1	Various deployments*	12
6.9.1	Hardware modularity*	3
7.1.1	Percent system availability	70
8.1.1	NORS rate	10
8.1.2	Volume of parts inventory	5
8.1.3	Ease of support*	5
8.2.1	Total power	30

* Qualitative MOE

TABLE E-3
(continued)

MOE		Utility
9.1.1	Ability to increase security*	4
9.2.1	Limitations of increase*	3
9.3.1	Ratio of secure-to-nonsecure*	10
9.4.1	Interface security requirements*	3
9.5.1	Compromise restoral*	15
9.6.1	Number subscribers end-to-end secure	15
9.6.2	Number subscribers link secure	10
9.6.3	Percent subscribers not end-to-end that can be upgraded	5
9.7.1	EMC/EMV intercept	25
10.1.1	Number of directory listings	3
10.1.2	Number of directory users	1
10.1.3	Number of personnel	1
10.1.4	Complexity of system*	5
10.2.1	Service features*	10
11.1.1	Number of equipment categories	10
12.1.1	Manhours preventive maintenance	8
12.1.2	Percent maintenance hours w/o equipment	2
12.1.3	Volume of preventive maintenance parts	2
12.1.4	Ease of preventive maintenance*	3
12.2.1	Manhours of corrective maintenance	5
12.2.2	Percent maintenance hours w/o equipment	2
12.2.3	Volume of corrective maintenance parts	2
12.2.4	NORM rate	8
12.2.5	Ease of corrective maintenance*	3
12.3.1	Manhours/language - continual	1
12.3.2	Manhours/language - special	1
12.3.3	Ease of software maintenance*	3
13.1.1	EMC/EMV spectrum requirements	10
13.2.1	RF spectrum flexibility*	20
14.1.1	EMC/EMV INTACS compatibility	15
14.2.1	EMC/EMV INTACS/other system compatibility	15
		1000 utiles

* Qualitative MOE



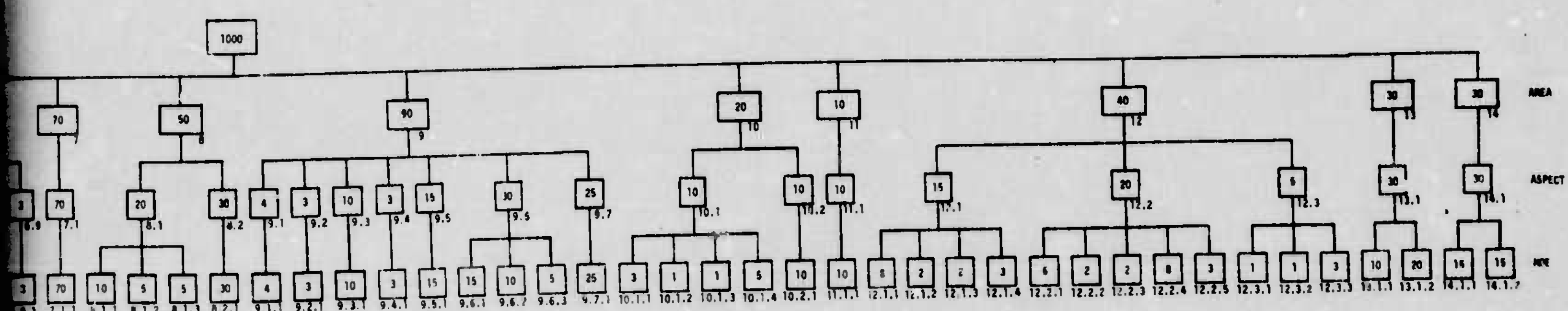


FIGURE E-1 Sample Utility Allocation

TABLE E-4
Parameter Values and Evaluation

MOE		Maximum Utility	Maximum Utility Parameter Value	Parameter Value			Utility Value	
				X	Y	Baseline	X	Y
1.1.1	Grade of service	110	1.00	.97	.95	.68	95	84
1.2.1	Speed of service	80	1.00	.98	.73	.42	77	41
1.3.1	System communicability score	70	95	86	62	51	64	26
2.1.1	Physical setup/teardown time	40	1	12	7	14	9	34
2.2.1	Percent GOS reduction during a move	45	15	26	31	70	42	38
2.2.2	Information intelligibility*	15	15	8	12	0	8	12
3.1.1	Volume of system	30	50	78	63	91	21	25
3.1.2	Weight of system	40	20	27	24	40	26	32
3.2.1	Percent transport vehicles organic	20	70	29	41	20	11	16
3.3.1	Portability*	20	20	11	18	0	11	18
4.1.1	FEBA centroid function	15	110	69	72	50	9	10
4.1.2	Susceptibility to destruction*	15	15	13	6	0	13	6
4.2.1	EMC/EMV direction-finding	60	90	72	69	38	54	43
5.1.1	Number of nodes destroyed to reduce GOS to specified level	6	5	4	1	1	5	0
5.1.2	Subscriber loss due to nodal destruction	6	2	7	13	20	4	2
5.1.3	Alternate capabilities*	3	3	3	2	0	3	2
5.2.1	EMC/EMV jamming vulnerability	25	90	64	66	62	4	8
6.1.1	Operational environment*	15	15	8	10	0	8	10
6.2.1	Force structure	6	6	3	3	0	3	3
6.3.1	Change in mission	5	5	4	2	0	4	2
6.4.1	Variation of data/voice traffic ratio	1	20	8	12	37	1	1
6.4.2	Data transmission*	1	1	0	0	0	0	0
6.5.1	Addition of subscribers*	2	2	1	0	0	1	0
6.6.1	Syatem modularity*	5	5	2	4	0	2	4
6.7.1	Downtime for CP displacement	10	3	6	4	6	0	8
6.8.1	Various deployments*	12	12	5	9	0	5	9
6.9.1	Hardware modularity*	3	3	1	2	0	1	2
7.1.1	Percent system availability	70	100	99	96	85	68	52
8.1.1	NORS rate	10	.02	.12	.13	.19	4	4
8.1.2	Volume of parts inventory	5	35	47	41	52	2	4
8.1.3	Ease of support*	5	5	2	2	0	2	2
8.2.1	Total power	30	12	23	22	19	-15	-10
9.1.1	Ability to increase security*	4	4	3	1	0	3	1
9.2.1	Limitations of increase*	3	3	2	0	0	2	0
9.3.1	Ratio of secure-to-nonsecure*	10	10	8	6	0	8	6
9.4.1	Interface security requirements*	3	3	2	3	0	2	3
9.5.1	Compromise restoral*	15	15	13	7	0	13	7

* Qualitative MOE

TABLE E-4
(continued)

MOE		Maximum Utility	Maximum Utility Parameter Value	Parameter Value			Utility Value	
				X	Y	Baseline	X	Y
9.6.1	Number of subscribers end-to-end secure	15	60	37	31	20	8	6
9.6.2	Number of subscribers link secure (not end-to-end)	10	95	83	70	57	7	5
9.6.3	Percent subscribers not end-to-end that can be upgraded	5	100	100	87	32	5	4
9.7.1	EMC/EMV intercept	25	10	13	19	21	18	11
10.1.1	Number of directory listings	3	0	48	26	10	-3	-1
10.1.2	Number of directory users	1	0	37	35	24	-1	-1
10.1.3	Number of personnel	1	20	19	18	27	1	1
10.1.4	Complexity of system*	5	5	2	4	0	2	4
10.2.1	Service features*	10	10	9	3	0	9	3
11.1.1	Number of equipment categories	10	20	65	61	53	-2	-1
12.1.1	Manhours preventive maintenance	8	10	22	20	23	0	1
12.1.2	Percent maintenance hours without equipment	2	60	70	74	81	1	1
12.1.3	Volume of preventive maintenance parts	2	10	14	13	17	1	1
12.1.4	Ease of preventive maintenance*	3	3	1	2	0	1	2
12.2.1	Manhours corrective maintenance	5	4	8	7	9	1	2
12.2.2	Percent maintenance hours without equipment	2	40	60	47	69	0	1
12.2.3	Volume of corrective maintenance parts	2	6	12	9	15	0	1
12.2.4	NORM rate	8	.25	.27	.35	.61	7	6
12.2.5	Ease of corrective maintenance*	3	3	2	2	0	2	2
12.3.1	Manhours/language - continual	1	15	53	48	22	-1	-1
12.3.2	Manhours/language - special	1	15	21	23	20	0	0
12.3.3	Ease of software maintenance*	3	3	1	1	0	1	1
13.1.1	EMC/EMV spectrum requirements	10	16	26	25	27	1	2
13.2.1	RF spectrum flexibility*	20	20	14	16	0	14	16
14.1.1	EMC/EMV INTACS compatibility	15	100	92	89	87	8	5
14.2.1	EMC/EMV INTACS/other system compatibility	15	100	92	91	85	8	8
		1000					658	574

* Qualitative MOE

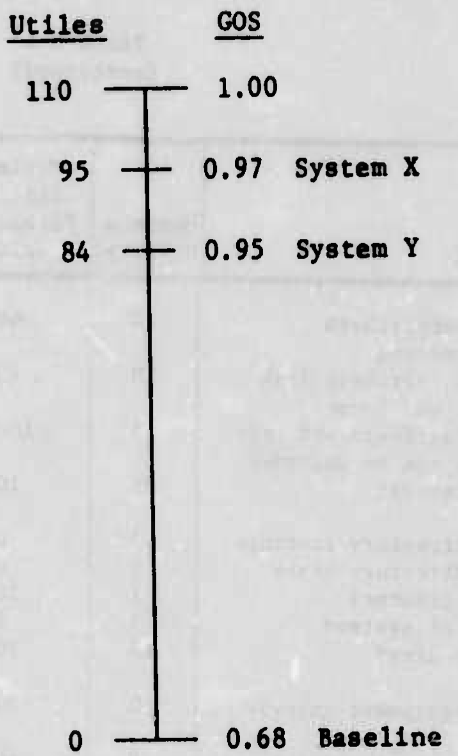


FIGURE E-2 Grade of Service Evaluation

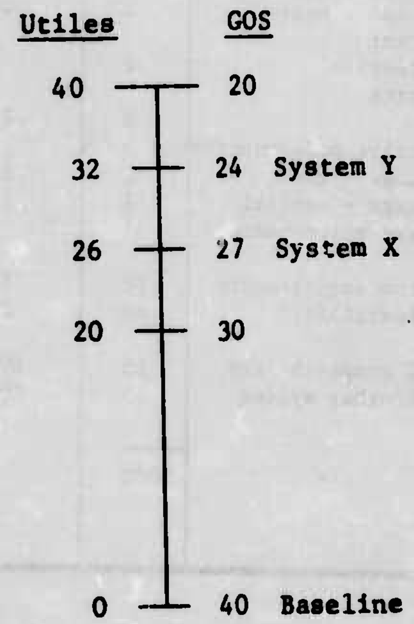


FIGURE E-3 System Weight Evaluation

practical. The evaluation results are presented in Table E-4, under "utility value". Next, each of these values is summed into the appropriate aspect (Table E-5), and the aspects are combined into areas (Table E-6).

The quantitative and qualitative MOEs may be added separately if desired, as shown in Tables E-7 and E-8, respectively.

To discover how one system differs from another (even if total utilities are the same), the evaluation process must be examined carefully. Each area and aspect that suggests significant distinction between the systems will be investigated. In the example under consideration, the most prominent area is quality of service, with a difference of 85 utiles between the systems. The primary sources of this are speed of service and information quality. Although it is not possible in this example, the Task V analysis will address an additional level of detail by discussing the actual system characteristics that contribute to those differences. This will aid the decision-maker in understanding the fundamental differences between the systems and how these differences are reflected in the analysis.

3.0 SENSITIVITY TO PARAMETER VARIATION

In this part of the analysis, each system parameter is varied a specified amount to determine the sensitivity of the FOM to this variation. Three parameter values of System X were reduced 5 percent to demonstrate the procedure. The first variation was for grade of service. A change from 97 to 92 decreased the utility by 24 utiles. Increasing the system weight by 5 percent reduced the utility by only 2 utiles, while a 5 percent variation in "reduction of GOS due to different ratios of data-to-voice traffic" produced no change in utility. The remainder of this analysis is presented in Table E-9. An obvious conclusion is that System X is quite sensitive to variations in grade of service, and care should be taken to ensure the validity of this number.

4.0 SENSITIVITY TO UTILITY ALLOCATION

Due to the use of human judgement, a lack of precision is inherent in the utility allocation. To gain some insight into the effect of these errors, a utility allocation sensitivity analysis is performed. A small variation (10 percent) is introduced in the utility allocation, and the resulting change in system utility is noted. To present the worst case for this example, utility allocations were reduced by 10 percent for each MOE in which the preferred System X scored higher than System Y. If Y was higher than X, the allocation was increased for the respective MOE. Even with this variation, System X was still preferred, 615.2 utiles to

TABLE E-5
Aspect Utility Evaluation

Areas and Aspects	Utility Value	
	X	Y
1. Quality of Service		
1.1 Grade of service	95	84
1.2 Speed of service	77	41
1.3 Information quality	64	26
2. Mobility		
2.1 Setup/teardown time	99	34
2.2 Communication during moves	50	50
3. Transportability		
3.1 Equipment size and weight	47	57
3.2 Vehicle requirements	11	16
3.3 Portability	11	18
4. Vulnerability		
4.1 Physical destruction	22	16
4.2 Susceptibility to direction-finding	54	43
5. Survivability		
5.1 Impact of nodal destruction	12	4
5.2 Impact of jamming	4	8
6. Flexibility		
6.1 Function in varying operational environments	8	10
6.2 Changes in force structure	3	3
6.3 Change of mission	4	2
6.4 Varying ratios of traffic	1	1
6.5 Impact of additional subscribers	1	0
6.6 System modularity	2	4
6.7 Downtime for CP displacement	0	8
6.8 Operation in varying deployments	5	9
6.9 Hardware modularity	1	2
7. Reliability		
7.1 System availability	68	52

TABLE E-5
(continued)

Areas and Aspects	Utility Value	
	X	Y
8. Logistical Support		
8.1 Required parts support	8	10
8.2 Power requirements	-15	-10
9. Security		
9.1 Provision for increased secure communications	3	1
9.2 Limitations due to increased security	2	0
9.3 Ratio of secure-to-nonsecure users	8	6
9.4 Interface security requirements	2	3
9.5 Restoration after compromise	13	7
9.6 Degree of security	20	15
9.7 Interceptibility	18	11
10. Operability		
10.1 Difficulty of system operation	-1	3
10.2 Service features	9	3
11. Standardization		
11.1 Multiplicity of CE equipment	-2	-1
12. Maintainability		
12.1 Provision of preventive maintenance	3	5
12.2 Provision of corrective maintenance	10	12
12.3 Provision of software update	0	0
13. RF Spectrum Requirements		
13.1 RF bandwidth requirements	1	2
13.2 Flexibility of frequency allocation	14	6
14. Electromagnetic Compatibility		
14.1 INTACS compatibility	8	5
14.2 INTACS/other system compatibility	8	8
	658	574 utiles

TABLE E-6
Total Utility Awarded Each Area

Area	Utility Value	
	X	Y
Quality of service	236	151
Mobility	59	84
Transportability	69	91
Vulnerability	76	59
Survivability	16	12
Flexibility	25	39
Reliability	68	52
Logistical support	-7	0
Security	66	43
Operability	8	6
Standardization	-2	-1
Maintainability	13	17
RF spectrum requirements	15	8
Electromagnetic compatibility	16	13
	658	574 utiles

TABLE E-7
MOE Utility (Quantitative) Awarded Each Area

Area	Utility Value X	Utility Value Y
Quality of service	236	151
Mobility	51	72
Transportability	58	73
Vulnerability	63	53
Survivability	13	10
Flexibility	1	9
Reliability	68	52
Logistical support	-9	-2
Security	38	26
Operability	-3	.01
Standardization	-2	01
Maintainability	9	12
RF spectrum requirements	1	2
Electromagnetic compatibility	16	13
	540	469 utiles

TABLE E-8

MOE Utility (Qualitative) Awarded Each Area

Area	Utility Value	
	X	Y
Quality of service	--	--
Mobility	8	12
Transportability	11	18
Vulnerability	13	6
Survivability	3	2
Flexibility	24	30
Reliability	--	--
Logistical support	2	2
Security	28	17
Operability	11	7
Standardization	--	--
Maintainability	4	5
RF spectrum requirements	14	6
Electromagnetic compatibility	--	--
	118	105 utiles

TABLE E-9

System X Parameter Sensitivity Analysis

MOE		Para-meter Value	Para-meter Vari-ation (±)	New Parameter Value		New Utility Value		Range of Utility Variation
				+	-	+	-	
1.1.1	Grade of service	.97	.05	1.00	.92	110	71	39
1.2.1	Speed of service	.98	.05	1.00	.93	80	69	11
1.3.1	System communicability score	86	4.3	90.3	81.7	67	56	11
2.1.1	Physical setup/teardown time	12	.6	12.6	11.4	8	11	3
2.2.1	Percent GOS reduction during a move	26	1.3	27.3	24.7	40	43	3
2.2.2	Information intelligibility*	8	.4	8.4	7.6	8.4	7.6	.8
3.1.1	Volume of system	78	4	82	74	19	22	3
3.1.2	Weight of system	27	1.4	28.4	25.6	24	29	5
3.2.1	Percent transport vehicles organic	29	1.6	30.6	27.4	12	10	2
3.3.1	Portability*	11	.6	11.6	10.4	11.6	10.4	1.2
4.1.1	FEBA centroid function	69	3.5	72.5	65.5	10	8	2
4.1.2	Susceptibility to destruction*	13	.7	13.7	12.3	13.7	12.3	1.4
4.2.1	EMC/EMV direction-finding	72	3.6	75.6	68.4	57	44	13
5.1.1	Number of nodes destroyed to reduce GOS to specified level	4	.2	4.2	3.8	5.1	4.5	6
5.1.2	Subscriber loss due to nodal destruction	7	.4	7.4	6.6	3.8	4.2	.4
5.1.3	Alternate capabilities*	3	.1	3.1	2.9	3.1	2.9	.2
5.2.1	EMC/EMV jamming vulnerability	64	3.2	67.2	60.8	10	3	7
6.1.1	Operational environment*	8	.4	8.4	7.6	8.4	7.6	.8
6.2.1	Force structure*	3	.1	3.1	2.9	3.1	2.9	.2
6.3.1	Change in mission*	4	.2	4.2	3.8	4.2	3.8	.4
6.4.1	Variation of data/voice traffic ratio	8	.4	8.4	7.6	1	1	0
6.4.2	Data transmission*	0	0	.1	0	.1	0	.1
6.5.1	Addition of subscribers*	1	.1	1.1	.9	1.1	.9	.2
6.6.1	System modularity*	2	.1	2.1	1.9	2.1	1.9	.2
6.7.1	Downtime for CP displacement	6	.3	6.3	5.7	0	9	9
6.8.1	Various deployments*	5	.3	5.3	4.7	5.3	4.7	.6
6.9.1	Hardware modularity*	1	.1	1.1	.9	1.1	.9	.2
7.1.1	Percent system availability	99	5	100	94	70	57	13
8.1.1	NORS rate	.12	.01	.13	.11	4	4	0
8.1.2	Volume of parts inventory	47	2.4	49.4	44.6	1	3	2
8.1.3	Ease of support*	2	.1	2.1	1.9	2.1	1.9	.2
8.2.1	Total power	23	1.2	24.2	21.8	-17	-10	7
9.1.1	Ability to increase security*	3	.2	3.2	2.8	3.2	2.8	.4
9.2.1	Limitations of increase*	2	.1	2.1	1.9	2.1	1.9	.2
9.3.1	Ratio of secure-to-nonsecure*	8	.4	8.4	7.6	8.4	7.6	.8

* Qualitative MOE

TABLE E-9
(continued)

MOE		Parameter Value	Parameter Variation (±)	New Parameter Value +	New Parameter Value -	New Utility Value +	New Utility Value -	Range of Utility Variation
9.4.1	Interface security requirements*	2	.1	2.1	1.9	2.1	1.9	.2
9.5.1	Compromise restoral*	13	.7	13.7	12.3	13.7	12.3	1.4
9.6.1	Number of subscribers end-to-end secure	37	1.9	38.9	35.1	9	7	2
9.6.2	Number of subscribers link secure (not end-to-end)	83	4.2	87.2	78.8	7.5	6	1.5
9.6.3	Percent subscribers not end-to-end that can be upgraded	100	5	100	95	5	4.8	.2
9.7.1	EMC/EMV intercept	13	.7	13.7	12.3	16.5	19	2.5
10.1.1	Number of directory listings	48	2.4	50.4	45.6	-3.1	-2.9	.2
10.1.2	Number of directory users	37	1.9	38.9	35.1	-1	-1	0
10.1.3	Number of personnel	19	1	20	18	1	1	0
10.1.4	Complexity of system*	2	.1	2.1	1.9	2.1	1.9	.2
10.2.1	Service features*	9	.5	9.5	8.5	9.5	8.5	1
11.1.1	Number of equipment categories	65	3.3	68.3	61.7	-2.5	-1	1.5
12.1.1	Manhours preventive maintenance	22	1.1	23.1	20.9	0	.8	.8
12.1.2	Percent maintenance hours without equipment	70	3.5	73.5	66.5	1	1	0
12.1.3	Volume of preventive maintenance parts	14	.7	14.7	13.3	1	1	0
12.1.4	Ease of preventive maintenance*	1	.1	1.1	.9	1.1	.9	.2
12.2.1	Manhours corrective maintenance	8	.4	8.4	7.6	.7	1.6	.9
12.2.2	Percent maintenance hours without equipment	60	3	63	57	0	.1	.1
12.2.3	Volume of corrective maintenance parts	12	.6	12.6	11.4	0	.5	.5
12.2.4	NORM rate	.27	.014	.284	.256	6.5	8	1.5
12.2.5	Ease of corrective maintenance*	2	.1	2.1	1.9	2.1	1.9	.2
12.3.1	Manhours/language - continual	53	2.6	55.6	50.4	-1	-1	0
12.3.2	Manhours/language - special	21	1.1	22.1	19.9	0	0	0
12.3.3	Ease of software maintenance*	1	.1	1.1	.9	1.1	.9	.2
13.1.1	EMC/EMV spectrum requirements	26	1.3	27.3	24.7	.5	3	2.5
13.2.1	RF spectrum flexibility*	14	.7	14.7	13.3	14.7	13.3	1.4
14.1.1	EMC/EMV INTACS compatibility	92	.5	97	87	12	4	8
14.2.1	EMC/EMV INTACS/other system compatibility	92	.5	97	87	12	4	8

* Qualitative MOE

559.0 utiles. If desired, this can be separated into qualitative and quantitative parts, as shown below.

	System X	System Y
Quantitative	500.2	449.9
Qualitative	115.0	108.1
Total	615.2	558.0

The information can also be generated for every area, aspect, and MOE.

The next step is to ascertain the percentage error required to make the two systems rank exactly equal. The necessary variation was calculated to be 31 percent. This allocation is presented in Table E-10 for each MOE, and is summed into the respective areas in Table E-11. If the analysis were based only on quantitative MOEs, the percentage change would be 34 percent. The exclusive use of qualitative MOEs would require a 21 percent variation to create equal ranking. The process could be repeated to establish the percent error at area or aspect levels for equal ranking.

TABLE E-10
Alternate Allocation of Utility to MOEs

MOE		Utility
1.1.1	Grade of service	83.1
1.2.1	Speed of service	60.3
1.3.1	System communicability score	52.8
2.1.1	Physical setup/teardown time	57.3
2.2.1	Percent GOS reduction during a move	33.9
2.2.2	Information intelligibility	21.5
3.1.1	Volume of system	43.0
3.1.2	Weight of system	57.3
3.2.1	Percent transport vehicles organic	28.6
3.3.1	Portability	28.6
4.1.1	FEBA centroid function	21.5
4.1.2	Susceptibility to destruction	11.4
4.2.1	EMC/EMV direction-finding	45.2
5.1.1	Number of nodes destroyed to reduce GOS to specified level	4.5
5.1.2	Subscriber loss due to nodal destruction	4.5
5.1.3	Alternate capabilities	2.3
5.2.1	EMC/EMV jamming vulnerability	35.8
6.1.1	Operational environment	21.5
6.2.1	Force structure	6.6
6.3.1	Change in mission	3.7
6.4.1	Variation of data/voice traffic ratio	1.1
6.4.2	Data transmission	1.1
6.5.1	Addition of subscribers	1.5
6.6.1	System modularity	7.2
6.7.1	Downtime for CP displacement	14.3
6.8.1	Various deployments	17.2
6.9.1	Hardware modularity	4.3
7.1.1	Percent system availability	52.8
8.1.1	NORS rate	10.9
8.1.2	Volume of parts inventory	7.2
8.1.3	Ease of support	5.5
8.2.1	Total power	43.0

TABLE E-10
(continued)

MOE		Utility
9.1.1	Ability to increase security	3.1
9.2.1	Limitations of increase	22.3
9.3.1	Ratio of secure-to-nonsecure	7.5
9.4.1	Interface security requirements	4.3
9.5.1	Compromise restoral	11.4
9.6.1	Number of subscribers end-to-end secure	11.4
9.6.2	Number of subscribers link secure	7.5
9.6.3	Percent subscribers not end-to-end that can be upgraded	3.7
9.7.1	EMC/EMV intercept	18.8
10.1.1	Number of directory listings	4.3
10.1.2	Number of directory users	1.1
10.1.3	Number of personnel	1.1
10.1.4	Complexity of system	7.2
10.2.1	Service features	7.5
11.1.1	Number of equipment categories	14.3
12.1.1	Manhours preventive maintenance	11.5
12.1.2	Percent maintenance hours without equipment	2.2
12.1.3	Volume of preventive maintenance parts	2.2
12.1.4	Ease of preventive maintenance	4.3
12.2.1	Manhours corrective maintenance	7.2
12.2.2	Percent maintenance hours without equipment	2.8
12.2.3	Volume of corrective maintenance parts	2.8
12.2.4	NORM rate	6.0
12.2.5	Ease of corrective maintenance	3.3
12.3.1	Manhours/language - continual	1.1
12.3.2	Manhours/language - special	1.1
12.3.3	Ease of software maintenance	3.3
13.1.1	EMC/EMV spectrum requirements	14.3
13.2.1	RF spectrum flexibility	15.1
14.1.1	EMC/EMV INTACS compatibility	11.4
14.2.1	EMC/EMV INTACS/other system compatibility	16.4
		1000.0 utiles

TABLE E-11
Alternate Utility Allocation by Area

Area	Utility
Quality of service	196.2
Mobility	112.7
Transportability	157.5
Vulnerability	78.1
Survivability	47.1
Flexibility	78.5
Reliability	52.8
Logistical support	66.6
Security	70.0
Operability	21.2
Standardization	14.3
Maintainability	47.8
RF spectrum requirements	29.4
Electromagnetic compatibility	27.8
	1000.0 utiles

APPENDIX F
COST/EFFECTIVENESS MODEL SENSITIVITY ANALYSIS

APPENDIX F
COST/EFFECTIVENESS MODEL SENSITIVITY ANALYSIS

1.0 REQUIREMENT FOR SENSITIVITY ANALYSIS

The effectiveness methodology for the INTACS evaluation contains 63 measures of effectiveness. Early in the evaluation, it must be determined that the model is a good model, and one way to make this determination is to conduct a sensitivity analysis of the impact on the system evaluation of changes in certain parameters. This will provide an indication that the model works if specific changes in input (variation in parameters that contribute to the value of MOEs) result in reasonable changes to output (system effectiveness as evaluated by these 63 MOEs).

This type of sensitivity analysis can, in fact, be conducted prior to beginning the actual evaluation of the candidate systems. Such an analysis will be relatively accurate if the evaluation can identify the contributing factors to each of the MOEs. (It is recognized that some factors contribute to more than one MOE.) After allocation of utiles to all 63 MOEs, the utile significance of a contributing factor can be determined. The factors can then be rank-ordered by utile significance, and this ranking will indicate the parameters to which the model is most sensitive. These results will provide an early indication of whether or not the model is a good model.

The remainder of this appendix will illustrate the results of such a sensitivity analysis: first, by developing the procedure for conducting the analysis; then by giving the results of the analysis; and finally, by providing the conclusions of the study team.

2.0 PROCEDURE

Certain MOEs are contributing factors to other MOEs. Figure F-1 illustrates the hypothetical relationship of four MOEs to two other MOEs. These same relationships are also illustrated in Table F-1, where contributing factors are indicated in the row for each MOE (i.e., C1 and C2 influence M1; C2, C3, and C4 influence M2). Summing cross marks down the columns yields the total number of MOEs influenced by each contributing factor.

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FIGURE F-1
Relationship of Contributing Factors to MOE

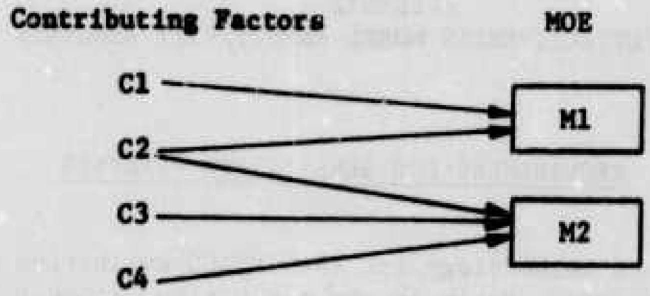

TABLE F-1
Identification of Contributing Factors
for Each MOE in Figure F-1

MOEs \ Contributing Factors	C1	C2	C3	C4
M1	X	X		
M2		X	X	X

Figure F-2 illustrates the possible significance of each contributing factor to the overall evaluation of each MOE. Similarly, Table F-2 depicts this relationship in the row for each MOE. Summing the fractions across any row will give a total of 1, implying that, in each case, some combination of these contributing factors yields a total evaluation of the MOE. Figure F-3 and Table F-3 specify some MOEs that might have the previously-described relationship.

For example, portability of a system is evaluated in terms of three other MOEs:

- Size
- Weight
- Hardware modularity.

The relative significance of these contributing factors to the total evaluation of portability might be:

- Size, 30 percent
- Weight, 40 percent
- Hardware modularity, 30 percent.

This means that a significant improvement in modularity might result in a 30 percent improvement in portability.

The relative significance of contributing factors to each MOE is estimated by a subjective procedure. When combined with the utility allocation for each MOE, the estimated total significances of each contributing factor can be calculated.

From the example in Appendix E, the utility allocation for these dependent MOEs is:

- Volume of parts inventory (5 utiles)
- Portability (20 utiles).

Table F-4 indicates the utile significance of the four contributing factors for these MOEs. The values in the table were obtained by multiplying the relative significance by the utility allocation. Table F-5 indicates the rank-ordering of these factors. The sensitivity analysis will develop a similar table for the 63 MOEs of the INTACS Study, using the utility allocation in Appendix E.

FIGURE F-2
Relative Significance of Contributing Factors to Each MOE

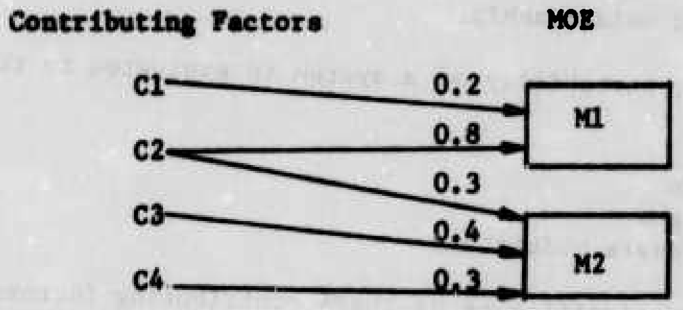

TABLE F-2
Relative Significance of Contributing Factors to Each MOE

MOEs \ Contributing Factors	C1	C2	C3	C4
M1	0.2	0.8		
M2		0.3	0.4	0.3

FIGURE F-3
Specific Example of Figure F-2

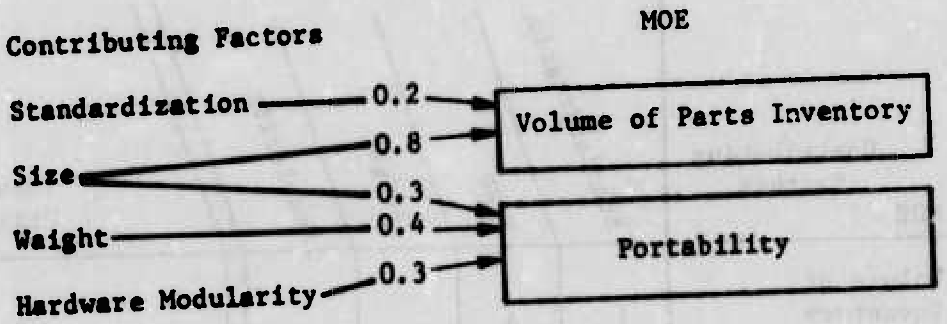

TABLE F-3
Specific Example of Table F-2

Contributing Factors / MOE	Standardization	Size	Weight	Modularity
Volume of Inventory	0.2	0.8		
Portability		0.3	0.4	0.3

TABLE F-4
Utile Significance of Contributing Factors

MOE \ Contributing Factors	Standardization	Size	Weight	Modularity		Total Utiles
Volume of Inventory	1	4				5
Portability		6	8	6		20
Total	1	10	8	6		25

TABLE F-5
Rank-Ordering of Contributing Factors
by Utile Significance

Contributing Factors	Utile Significance	Rank
Standardization	1	4
Size	10	1
Weight	8	2
Modularity	6	3

3.0 RESULTS OF SENSITIVITY ANALYSIS

The contributing factors for each of the 63 MOEs were identified, and their relative significance was indicated in a manner similar to previously described examples. Table F-6 indicates the relative significance of all contributing factors for the MOEs. (These contributing factors are actually 26 of the 63 MOEs.) Table F-7 indicates the utile significance of these contributing factors. Table F-8 indicates the system sensitivity to improvement of the contributing MOEs, which are listed in order of ranking from greatest to least system significance.

Grade of service was found to be more than twice as significant as any other MOE. Speed of service and the susceptibility of transmitters to direction-finding are considered to be relatively equal in significance. Equipment weight is considered to be more significant than equipment size.

As can be observed from the ranking, no correlation was made (nor was any intended) between utility significance and the number of MOEs influenced. Equipment size influenced the greatest number of MOEs (13), and yet this factor ranked eighth in system significance. Speed of service influenced only one MOE, and yet it ranked third in system significance.

TABLE F-6
Relative Significance of Contributing Factors

	GOS	SOS	Communicability	Setup/Teardown Time	S/N Threshold	Size	Weight	FEBA	Direction-Finding	Alternate Capabilities	Jamming	Hardware Modularity	Availability	Ease of Logistical Support	Power Requirements	Ability to Increase Security	No. End-to-End Secure	No. Link Secure	MOS Requirements	Complexity	Service Features	Standardization	Ease of Preventive Maintenance	Ease of Corrective Maintenance	Ease of Software Update	RF Spectrum
Grade of Service	1																									
Speed of Service		1																								
Communicability			1																							
Setup/Teardown Time				.7								.2							.1							
GOS Reduction during Move	.8											.2														
Δ Information Intelligibility (S/N)					1																					
Size of System						1																				
Weight of System							1																			
Percent Organic Vehicles						.5	.5																			
Portability						.3	.4					.3														
FEBA Centroid Function								1																		
Susceptibility to Destruction				.3		.05		.35	.3																	
Susceptibility to Direction-Finding									1																	
GOS Loss/Nodal Destruction	1																									
Subscriber Loss/Nodal Destruction										1																
Alternate Capabilities										1																
Impact of Jamming											1															
Operational Environment	.15			.1	.05	.05	.1			.1	.2				.05										05	.15
Force Structure	.2				.1	.05	.05								.2										.2	.2
Change to Mission	.25			.1	.1	.1	.05			.1	.2				.05										.05	
Variation of Data/Voice Ratio	1																									
Data Transmission					.3						.3														.4	
Additional Subscribers	.15																					.05				.6
System Modularity	.35				.35																					.3
Downtime for CP Displacement	.25			.35								.4														
Various Deployments	.15			.05	.05	.05	.1			.1	.2				.1										.05	.15
Hardware Modularity												1														
Availability													1													
NORS Rate														1												
Volume of Parts Inventory						.8																.2				
Ease of Logistical Support														.9								.1				
Total Power Requirements															1											
Ability to Increase Security				.1												.3	.2	.2								.2
Limitations of Increase				.1	.1	.05	.05									.2	.2	.2								.1
Ratio of Secure to Nonsecure						.05	.05									.2	.3	.3								.1
Interface Security Requirements																1										
Compromise Restoral																1										
No. End-to-End Secure																	1									
No. Link Secure																		1								
Percent Upgradable to End-to-End												1														
Interceptibility					.3				.7																	
No. Directory Listings																				1						
No. Directory Users																				1						
MOS Requirements																			1							
Complexity of System																				1						
Service Features																					1					
Standardization												.2										.8				
MOS for Preventive Maintenance																			1							
Preventive Maint w/o Test Equipment																							1			
Volume of Preventive Maint Parts						.8																.2				
Ease of Preventive Maintenance																			.3				.7			
MOS for Corrective Maintenance																			1							
Corrective Maint w/o Test Equipment																								1		
Volume of Corrective Maint Parts						.8																.2				
NORM Rate													.2						.3					.5		
Ease of Corrective Maintenance																			.3					.7		
Manhours/Language Continual																									1	
Manhours/Language Special																									1	
Ease of Software Update																			.3						.7	
RF Spectrum Utilization																										1
RF Spectrum Flexibility																										1
Compatibility			.3																							[illegible]
Compatibility with Other Systems			.3																							[illegible]

TABLE F-7

Utile Significance of Contributing Factors

		GOS	SOS	Communicability	Setup/Teardown Time	S/N Threshold	Size	Weight	FEBA	Direction-Finding	Alternate Capabilities	Jamming	Hardware Modularity	Availability	Ease of Logistical Support	Power Requirements	Ability to Increase Security	No. End-to-End Secure	No. Link Secure	MOS Requirements	Complexity	Service Features	Standardization	Ease of Preventive Maint	Ease of Corrective Maint	Ease of Software Update	RF Spectrum
Grade of Service	110	110																									
Speed of Service	80		80																								
Communicability	70			70																							
Setup/Teardown Time	40				28								8							4							
GOS Reduction during Move	45	36											9														
∆ Information Intelligibility (S/N)	15					15																					
Size of System	30						30																				
Weight of System	40							40																			
Percent Organic Vehicles	20						10	10																			
Portability	20						6	8					6														
FEBA Centroid Function	15								15																		
Susceptibility to Destruction	15				4.5		.75		5.25	4.5																	
Susceptibility to Direction-Finding	60									60																	
GOS Loss/Nodal Destruction	6	6																									
Subscriber Loss/Nodal Destruction	8										6																
Alternate Capabilities	3										3																
Impact of Jamming	25											25															
Operational Environment	15	2.75			1.5	.75	.75	1.5			1.5	3				.75										.75	2.25
Force Structure	6	1.2				.6	.3	.3								1.2										1.2	1.2
Change in Mission	5	1.25			.5	.5	.5	.25			.5	.1				.25										.25	.75
Variation of Data/Voice Ratio	1	1																									
Data Transmission	1					.3						.3														.4	
Additional Subscribers	2	.3																									1.6
System Modularity	5	1.75				1.75																					1.5
Downtime for CP Displacement	10	2.5			3.5								4														
Various Deployments	12	1.8			.6	.6	.6	1.2			1.2	2.4				1.2										.6	1.8
Hardware Modularity	3												3														
Availability	70													70													
NORS Rate	10														10												
Volume of Parts Inventory	5						4																1				
Ease of Logistical Support	5														4.5								.5				
Total Power Requirements	30															30											
Ability to Increase Security	4				.4												1.2	.8	.8								.8
Limitations of Increase	3				.3	.3	.15	.15									.6	.6	.6								.1
Ratio of Secure to Nonsecure	10						.5	.5									2	3	3								.1
Interface Security Requirements	3																3										
Compromise Restoral	15																15										
No. End-to-End Secure	15																	15									
No. Link Secure	10																		10								
Percent Upgradable to End-to-End	5												5														
Interceptibility	25					7.5				17.5																	
No. Directory Listings	3																				3						
No. Directory Users	1																				1						
MOS Requirements	1																			1							
Complexity of System	5																				5						
Service Features	10																					10					
Standardization	10												2										8				
MOS for Preventive Maintenance	8																			8							
Preventive Maint w/o Test Equipment	2																							2			
Volume of Preventive Maint Parts	2						1.6																.4				
Ease of Preventive Maintenance	3																			.9				2.1			
MOS for Corrective Maintenance	5																			5							
Corrective Maint w/o Test Equipment	2																								2		
Volume of Corrective Maint Parts	2						1.6																.4				
NCRM Rate	5													1.6						2.4					[illegible]		
Ease of Corrective Maintenance	3																			.9					2.1		
Manhours/Language Continual	1																									1	
Manhours/Language Special	1																									1	
Ease of Software Update	3																			.9						2.1	
RF Spectrum Utilization	10																										10
RF Spectrum Flexibility	20																										20
Compatibility	15					4.5																					10.5
Compatibility with Other Systems	15					4.5																					10.5
Totals		164.05	80	70	39.3	36.3	58.75	61.9	20.25	82	12.2	31.7	37	71.8	14.5	33.4	21.8	19.4	14.4	23.1	9	10	10.6	4.1	8.1	7.1	61.45

TABLE F-8
System Sensitivity to Improvement of Contributing MOEs

MOE	MOE Utile Allocation	Utile Significance of MOE to System	System Utile Improvement**	Number of MOEs Influenced	10 Percent MOE Allocation	System Utile Improvement for 10 Percent MOE Utile Improvement
Grade of service	110	164.05	1.49	11	11.0	16.41
Direction-finding	60	82	1.37	3	6.0	8.2
Speed of service	80	80	1.00	1	8.0	8.0
Availability	70	71.6	1.02	2	7.0	7.16
Communicability	70	70	1.00	1	7.0	7.0
Weight	40	61.9	1.55	9	4.0	6.19
RF spectrum	10	61.45	6.15	12	1.0	6.15
Size	30	56.75	1.89	13	3.0	5.68
Setup/teardown time	28* (40)	39.3	1.40	8	2.8	3.93
Hardware modularity	3	37	12.33	7	0.3	3.7
S/N threshold	15	36.3	2.42	11	1.5	3.63
Power requirements	30	33.4	1.11	5	3.0	3.34
Impact of jamming	25	31.7	1.27	5	2.5	3.17
MOS requirements	1	23.1	23.10	8	0.1	2.31
Ability to increase security	1.2* (4)	21.8	18.17	5	0.12	2.18
FEBA centroid function	15	20.25	1.35	2	1.5	2.03
Number of end-to-end secure	15	19.4	1.29	4	1.5	1.94
Ease of logistical support	4.5* (5)	14.5	3.22	2	0.45	1.45
Number of link secure	10	14.4	1.44	2	1.0	1.44
Alternate capabilities	3	12.2	4.07	5	0.3	1.22
Standardization	8* (10)	10.4	1.30	6	0.8	1.04
Service features	10	10	1.00	1	1.0	1.0
Complexity	5	9	1.80	3	0.5	0.9
Ease of corrective maint	2.1* (3)	8.1	3.86	3	0.21	0.81
Ease of software update	2.1* (3)	7.3	3.48	8	0.21	0.73
Ease of preventive maint	2.1* (3)	4.1	1.95	2	0.21	0.41

* These MOEs are evaluated (in part) in terms of other MOEs. The total utile allocation is indicated in brackets; however, the utile allocation used in the calculations for this table results from subtracting the utiles attributable to these other MOEs.

** System sensitivity to MOE improvement of one utile.

3.1 IMPACT OF HIGH VARIATION OF PARAMETERS

Tables F-6, F-7, and F-8 illustrate the significance of 26 contributing MOEs to the effectiveness evaluation. These tables are based upon the expected contribution of each MOE under what could be termed "normal conditions", where the values for the MOEs (parameters) do not undergo extreme variation.

In a further analysis, the relative significance of contributing MOEs was estimated for conditions of high parameter variation. That is, the values for each of these measures differ significantly among the alternative concepts. The results of this additional consideration are indicated in Tables F-9 (relative significance) and F-10 (utile significance). A comparison of the differing results of normal and high parameter variation is indicated in Table F-11. As can be seen from this table, high parameter change somewhat modifies the relative significance of certain contributing MOEs. For example, hardware modularity is reduced in significance by greater than 50 percent. Three MOEs that become more significant under conditions of high parameter change are the ability to provide increased security, distance from FEBA, and alternate capabilities.

The study team found that the results of this sensitivity analysis indicated the model was properly sensitive to parameter variation. Using the procedure developed above, this sensitivity analysis can be checked during the course of the evaluation.

TABLE F-9
Relative Significance of Contributing Factors
(for Significant Variation of Contributing Factors)

	GOS	SOS	Communicability	Setup/Teardown Time	S/N Threshold	Size	Weight	FEBA	Direction-Finding	Alternate Capabilities	Jamming	Hardware Modularity	Availability	Ease of Logistical Support	Power Requirements	Ability to Increase Security	No. End-to-End Secure	No. Link Secure	MOS Requirements	Complexity	Service Features	Standardization	Ease of Preventive Maintenance	Ease of Corrective Maintenance	Ease of Software Update	RF Spectrum
Grade of Service	1																									
Speed of Service		1																								
Communicability			1																							
Setup/Teardown Time				.9															.1							
GOS Reduction during Move	.8									.2																
Δ Information intelligibility (S/N)					1																					
Size of System						1																				
Weight of System							1																			
Percent Organic Vehicles						.5	.5																			
Portability						.4	.4					.2														
FEBA Centroid Function								1																		
Susceptibility to Destruction						.1		.5	.4																	
Susceptibility to Direction-Finding									1																	
GOS Loss/Nodal Destruction	.4									.6																
Subscriber Loss/Nodal Destruction										1																
Alternate Capabilities										1																
Impact of Jamming											1															
Operational Environment	.2				.2	.1	.1		.1		.1				.1											.1
Force Structure	.25														.25										.25	.25
Change in Mission	.2			.4											.1											.1
Variation of Data/Voice Ratio	.5				.3																					.2
Data Transmission					.3						.3															.4
Additional Subscribers	.4				.2																					.3
System Modularity	.3				.4																					.1
Downtime for CP Displacement	.2			.5								.3														
Various Deployments	.2				.1		.1			.1	.2				.1											.2
Hardware Modularity												1														
Availability													1													
NORS Rate													.3	.7												
Volume of Parts Inventory						1																				
Ease of Logistical Support														1												
Total Power Requirements															1											
Ability to Increase Security																1										
Limitations of Increase					.1	.1	.1	.2			.1			.1		.1										.2
Ratio of Secure to Nonsecure								.2								.6										.2
Interface Security Requirements																1										
Compromise Material																1										
No. End-to-End Secure																	1									
No. Link Secure																		1								
Percent Upgradable to End-to-End												1														
Interceptibility					.1				.9																	
No. Directory Listings																				1						
No. Directory Users																				1						
MOS Requirements																			1							
Complexity of System																				1						
Service Features																					[illegible]					
Standardization												.1										.9				
MOS for Preventive Maintenance																			1							
Preventive Maint w/o Test Equipment																							1			
Volume of Preventive Maint Parts						.6							.1									.1				
Ease of Preventive Maintenance																							[illegible]			
MOS for Corrective Maintenance																			1							
Corrective Maint w/o Test Equipment																								[illegible]		
Volume of Corrective Maint Parts						.7																.1				
NORM Rate													.5						.5							
Ease of Corrective Maintenance																								[illegible]		
Manhours/Language Continual																									[illegible]	
Manhours/Language Special																									[illegible]	
Ease of Software Update																									[illegible]	
RF Spectrum Utilization																										[illegible]
RF Spectrum Flexibility																										[illegible]
Compatibility					.5																					[illegible]
Compatibility with Other Systems					.5																					[illegible]

TABLE F-10
Utile Significance of Contributing Factors
(for Significant Variation of Contributing Factors)

		GOS	SOS	Communicability	Setup/Teardown Time	S/N Threshold	Size	Weight	FEBA	Direction-Finding	Alternate Capabilities	Jamming	Hardware Modularity	Availability	Ease of Logistical Support	Power Requirements	Ability to Increase Security	No. End-to-End Secure	No. Link Secure	MDS Requirements	Complexity	Service Features	Standardization	Ease of Preventive Maint	Ease of Corrective Maint	Ease of Software Update	RF Spe[illegible]
Grade of Service	110	110																									
Speed of Service	80		80																								
Communicability	70			70																							
Setup/Teardown Time	40				36																						
GOS Reduction during Move	45	36									9																
Δ Information Intelligibility (S/N)	15					15																					
Size of System	30						30																				
Weight of System	40							40																			
Percent Organic Vehicles	20						10	10																			
Portability	20						8	8					4														
FEBA Centroid Function	15								15																		
Susceptibility to Destruction	15						1.5		7.5	4																	
Susceptibility to Direction-Finding	60									60																	
GOS Loss/Nodal Destruction	6	2.4									3.6																
Subscriber Loss/Nodal Destruction	6										6																
Alternate Capabilities	3										3																
Impact of Jamming	25											25															
Operational Environment	15	3				3	1.5	1.5		1.5		1.5				1.5											1.5
Force Structure	6	1.5														1.5										1.5	1.5
Change in Mission	5	1			2											.5											1.5
Variation of Data/Voice Ratio	1	.5				.3																					.2
Data Transmission	1					.3						.3															.4
Additional Subscribers	7	.8				.4																					.8
System Modularity	5	1.5				2																					1.5
Downtime for CP Displacement	10	2			5								3														
Various Deployments	12	2.4				1.2		1.2			1.2	2.4				1.2											2.4
Hardware Modularity	3												3														
Availability	70													70													
NORS Rate	10													3	7												
Volume of Parts Inventory	5						5																				
Ease of Logistical Support	5														5												
Total Power Requirements	30															30											
Ability to Increase Security	4																4										
Limitations of Increase	3					.3	.3	.3	.6			.3			.3		.3										[illegible]
Ratio of Secure to Nonsecure	10								2								6										
Interface Security Requirements	3																3										
Compromise Restoral	15																15										
No. End-to-End Secure	15																	15									
No. Link Secure	10																		10								
Percent Upgradable to End-to-End	5												5														
Interceptibility	25					2.5				22.5																	
No. Directory Listings	3																				3						
No. Directory Users	1																				1						
MDS Requirements	1																			1							
Complexity of System	5																				5						
Service Features	10																					10					
Standardization	10												1										9				
MDS for Preventive Maintenance	8																			8							
Preventive Maint w/o Test Equipment	2																						.6				
Volume of Preventive Maint Parts	2						1.2							.2													
Ease of Preventive Maintenance	3																							[illegible]			
MOS for Corrective Maintenance	5																			5							
Corrective Maint w/o Test Equipment	2																						.4				
Volume of Corrective Maint Parts	1						1.2							.2													
NORM Rate	5													4						4							
Ease of Corrective Maintenance	3																										
Manhours/Language Continual	1																										
Manhours/Language Special	1																										
Ease of Software Update	3																										
RF Spectrum Utilization	10																										10
RF Spectrum Flexibility	20																										20
Compatibility	15					7.5																					7.5
Compatibility with Other Systems	15					7.5																					[illegible]
Totals		161.1	80	70	43	40	5[illegible].7	61	25.1	90	22.8	29.5	16	77.4	12.3	34.7	28.3	15	10	22	9	10	10.[illegible]	5	[illegible]	[illegible]	[illegible]

TABLE F-11
Utile Significance

MOE	Parameter Change		Rank	
	Normal	High	Normal	High
Grade of service	164.05	161.1	1	1
Direction-finding	82	90	2	2
Speed of service	80	80	3	3
Availability	71.6	77.4	4	4
Communicability	70	70	5	5
Weight	61.9	61	6	6
RF spectrum	61.45	57.4	7	7
Size	56.75	58.7	8	8
Setup/teardown	39.3	43	9	9
Modularity	37	16	10	17
S/N threshold	36.3	40	11	10
Power requirements	33.4	34.7	12	11
Jamming	31.7	29.5	13	12
MOS requirements	23.1	22	14	16
Ability to increase security	21.8	28.3	15	13
FEBA centroid function	20.25	25.1	16	14
Number end-to-end secure	19.4	15	17	18
Ease of logistical support	14.5	12.3	18	19
Number link secure	14.4	10	19	21
Alternate capabilities	12.2	22.8	20	15
Standardization	10.4	10.2	21	20
Service features	10	10	22	21
Complexity	9	9	23	24
Ease of corrective maintenance	8.1	5	24	25
Ease of software updates	7.3	6.5	25	24
Ease of preventive maintenance	4.1	5	26	25

4.0 IMPACT OF ELIMINATION OF LEAST SIGNIFICANT MOEs

Reduction of the number of MOEs required in the evaluation of the alternative systems is highly desirable; therefore, a study was conducted of the likely impact of such a reduction, by considering the same evaluation discussed in Appendix E.

The 26 MOEs that receive the greatest allocation of utiles were identified and isolated for a separate evaluation. Table F-12 lists these MOEs and provides the utile significance of their contributing factors. Table F-13 lists the total utile significance of the contributing factors and compares the ranking of these factors when 63 and 26 MOEs are considered. As can be observed, the 17 most significant contributing factors for the 63 MOEs are also the 17 most significant contributing factors when only 26 MOEs are considered, and no major changes occurred in the ordering of these factors.

Table F-14 lists the 26 MOEs and the utile allocation for sample Systems X and Y from Appendix E. The system ranking remains unchanged when only 26 MOEs are used. In fact, the relative superiority of System X over System Y is 14.8 percent when 63 MOEs are considered, and 15.2 percent when only 23 MOEs are considered. Thus, use of the 26 primary MOEs accounted for 80.5 percent of the total utiles allocated, and resulted in no appreciable difference in system ranking.

This method for reducing the number of MOEs that contribute to the system evaluation could be applied in Task V after the study team is provided the actual utile allocation. All other MOEs could then be addressed in narrative form to compare the systems, but need not contribute to the total utility for each system.

TABLE F-12
Utile Significance of Contributing Factors for 23 Primary MOEs

		Grade of service	Speed of service	Communicability	Setup/teardown time	S/N threshold	Size	Weight	FEBA	Direction-finding	Alternate capabilities	Jamming	Hardware modularity	Availability	Power requirements	Ability to increase security	Number of end-to-end secure	MOS requirements	Ease of software update	RF spectrum
Grade of service	110	110																		
Speed of service	80		80																	
Communicability	70			70																
Setup/teardown time	40				28								8					4		
GOS reduction during move	45	36											9							
Δ information intelligibility (S/N)	15						15													
Size of system	30							30												
Weight of system	40								40											
Percent organic vehicles	20							10	10											
Portability	20							6	8				6							
FEBA centroid function	15									15										
Susceptibility to destruction	15				4.5			.75		5.25	4.5									
Susceptibility to direction-finding	60										60									
Impact of jamming	25												25							
Operational environment	15	2.25			1.5	.75	.75	1.5				1.5	3		.75				.75	2.25
Availability	70													70						
Power requirements	30														30					
Compromise restoral	15															15				
Number end-to-end secure	15																15			
Interceptibility	25					7.5					17.5									
RF spectrum flexibility	20																			20
Compatibility	15					4.5														10.5
Compatibility with other systems	15					4.5														10.5
Total		148.25	80	70	34	32.25	47.5	59.5	20.25	82	1.5	28	23	70	30.75	15	15	4	.75	43.25

TABLE F-13
Utile Significance of Contributing Factors
for 26 Primary MOEs

MOE	Parameter Change		Rank	
	Normal	High	Normal	High
Grade of service	164.05	148.25	1	1
Direction-finding	82	82	2	2
Speed of service	80	80	3	3
Availability	71.6	70	4	4
Communicability	70	70	5	5
Weight	61.9	59.5	6	6
RF spectrum	61.45	43.25	7	8
Size	56.75	47.5	8	7
Setup/teardown	39.3	34	9	9
Modularity	37	23	10	13
S/N threshold	36.3	32.25	11	10
Power requirements	33.4	30.75	12	11
Jamming	31.7	28	13	12
MOS requirements	23.1	4	14	17
Ability to increase security	21.8	15	15	15
FEBA centroid function	20.25	20.25	16	14
Number of end-to-end secure	19.4	15	17	15
Ease of logistical support	14.5	--	18	--
Number of link secure	14.4	--	19	--
Alternate capabilities	12.2	1.5	20	18
Standardization	10.4	--	21	--
Service features	10	--	22	--
Complexity	9	--	23	--
Ease of corrective maintenance	8.1	--	24	--
Ease of software update	7.3	0.75	25	19
Ease of preventive maintenance	4.1	--	26	--

TABLE F-14
Utility Values for 23 Primary MOEs
and Sample Systems X and Y

MOE		Maximum Utility	Utility Value	
			X	Y
1.1.1	Grade of service	110	95	84
1.2.1	Speed of service	80	77	41
1.3.1	Communicability	70	64	26
2.1.1	Setup/teardown time	40	9	34
2.2.1	GOS reduction during move	45	42	38
2.2.2	Information intelligibility*	15	8	12
3.1.1	Volume of system	30	21	25
3.1.2	Weight of system	40	26	32
3.2.1	Percent transport vehicles organic	20	11	16
3.3.1	Portability*	20	11	18
4.1.1	FEBA centroid function	15	9	10
4.1.2	Susceptibility to destruction*	15	13	6
4.2.1	Direction-finding	60	54	43
5.2.1	Jamming vulnerability	25	4	8
6.1.1	Operational environment*	15	8	10
7.1.1	Percent system availability	70	68	52
8.2.1	Total power	30	-15	-10
9.5.1	Compromise restoral*	15	13	7
9.6.1	Number of subscribers end-to-end secure	15	8	6
9.7.1	Interceptibility	25	18	11
13.2.1	RF spectrum flexibility*	20	14	16
14.1.1	INTACS compatibility	15	8	5
14.2.1	INTACS/other system compatibility	15	8	8
		805	574	498

* Qualitative MOE

5.0 DEPENDENCE OF EFFECTIVENESS METHODOLOGY ON SUBJECTIVE JUDGEMENT

Subjective judgement is required throughout the INTACS methodology for evaluating system effectiveness. Figure F-4 illustrates a judgement trail from the pre-evaluation allocation of utiles for each MOE to the post-evaluation assignment of utiles for the specific value of each MOE. Four separate stages in the system evaluation are specified:

- Allocation of utiles
- Input data and conditions
- Evaluation procedure
- Assignment of utiles.

The initial allocation of utiles normally requires subjective judgement at three levels: areas, aspects, and measures of effectiveness. However, for some MOEs, judgement at all three levels is unnecessary (e.g., in the case of only one aspect within an area or only one MOE within an aspect).

The input data and conditions relate only to quantitative MOEs, since the entire evaluation of qualitative MOEs is considered a single subjective judgement, with relevant conditions noted but not measured. Several of the quantitative MOEs require COMSR data as direct or indirect input. The determination of COMSRs was, in part, a judgemental exercise. MOEs that require the scenario and specified deployment as a frame of reference are requiring additional subjective judgement.

The evaluation procedure is subjective, of course, for all qualitative MOEs. Some of the quantitative MOEs will be evaluated by the network models (CASE and SIMCE) or by the IPM. These MOEs, and many more, are based upon a sized system, which is an additional dependence on SIMCE. While the network models attempt to represent telephone, teletype, and data networks, they are partly the result of (previously made) judgement as to what approximations are acceptable as representative of such networks. Thus, to the extent that the model is not totally representative of telephone, teletype, or data networks, a degree of subjective judgement can be traced to the use of these models. Additionally, some MOEs require assignment of weights to the output of these models.

Finally, the assignment of utiles to the evaluated MOEs requires subjective judgement as to the relative significance of improvement (or degradation) from the baseline system.

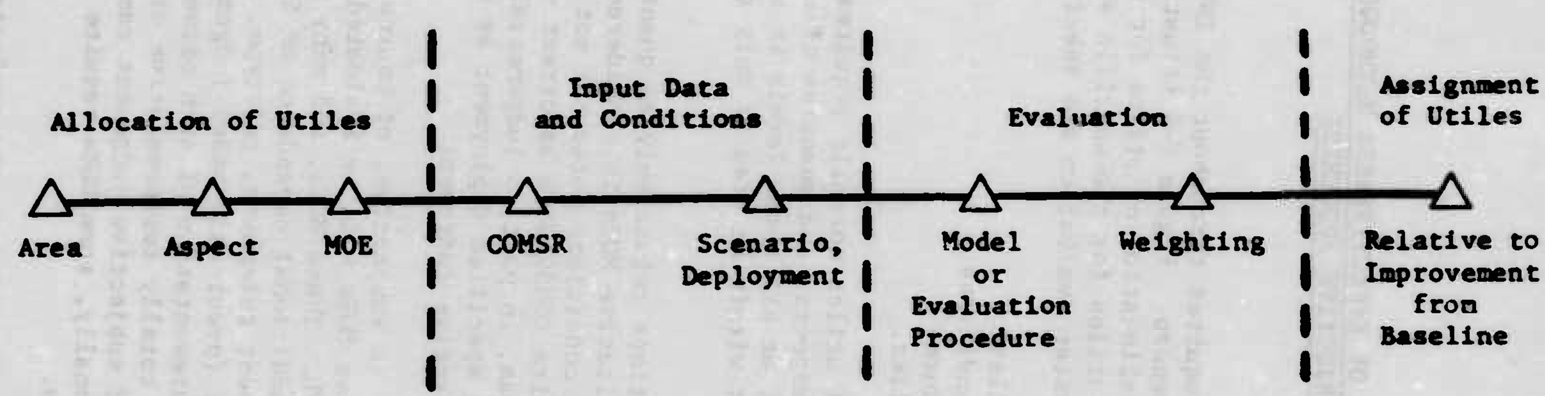

FIGURE F-4 Judgement Trail for Effectiveness Methodology

Figure F-5 illustrates the judgement trail for the quantitative MOE grade of service. Similarly, Figure F-6 is the judgement trail for the qualitative MOE ability to function in various operational environments.

For the output of Task V to be meaningful, the frequency and nature of the application of subjective judgement should be fully understood. Throughout the evaluation, results of such judgement will be identified, thus enabling a reevaluation by those who would disagree. While the effectiveness evaluation is heavily dependent on judgement, this provides the advantage of permitting consideration of a broader spectrum of system capabilities to determine overall system performance.

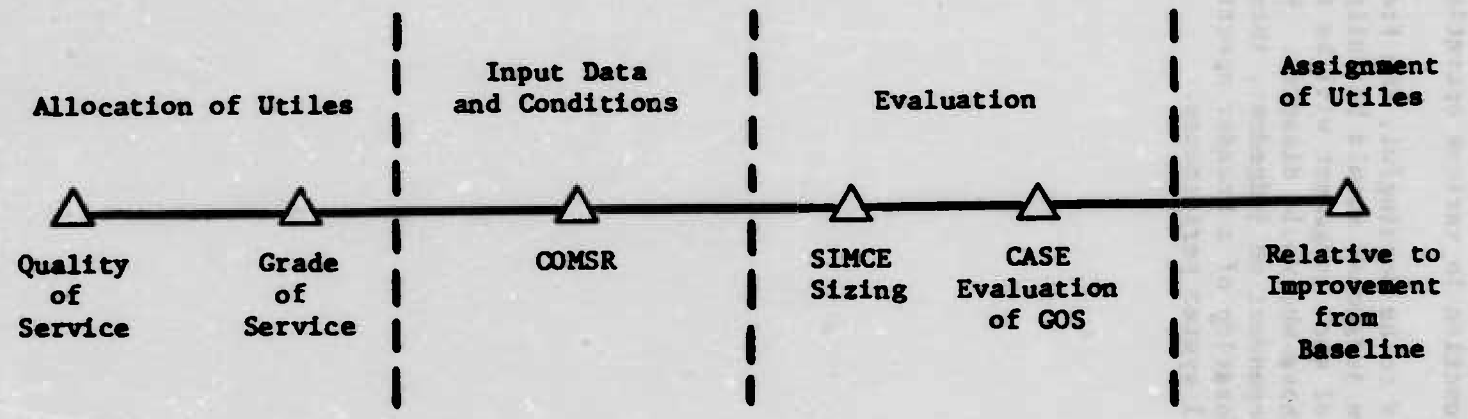

FIGURE F-5 Judgement Trail for Grade of Service MOE

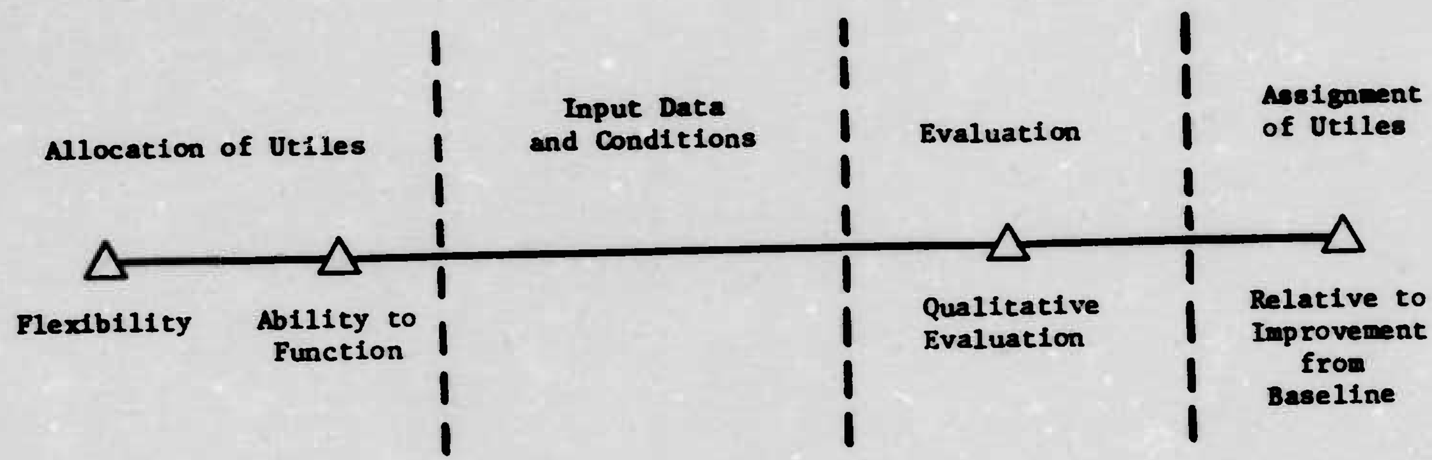

FIGURE F-6 Judgement Trail for
Ability to Function in Various Operational Environments

APPENDIX G
EVALUATION OF SINGLE-CHANNEL SYSTEMS
IN THE MID RANGE TIME FRAME

APPENDIX G
EVALUATION OF SINGLE-CHANNEL SYSTEMS
IN THE MID RANGE TIME FRAME

1.0 COMMUNICATIONS SUPPORT REQUIREMENTS

The COMSRs specify communications requirements by mode, precedence, message length, security classification, and originator access need (land-fixed, land-mobile, airborne, and waterborne). All traffic with other than fixed access is considered to be a requirement for single-channel. Thus, the need for mobility has generated a need for single-channel capabilities.

When a specific need for single channel exists, system designers will provide that capability, selecting and assigning equipment based primarily upon range, mobility, and reliability requirements. In addition to specific dictation of the need for single channel by the COMSRs, single channel will also be considered as an alternative in satisfying other communications support requirements. In these instances, if single channel is selected, the rationale behind the selection will be documented.

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2.0 CONCEPT DESIGN FEATURES FOR SINGLE CHANNEL

Two communications functional areas particularly applicable to single channel are:

- Single-channel transmission facilities
- Single-channel access to multichannel switching.

Single-channel transmission facilities include VHF/FM net radio, HF/SSB RATT single-channel TACSAT, and TRCS. Upgraded TACSAT single-channel (UHF) transmission facilities will be introduced into the inventory during the mid range time frame. These equipments will be considered in cases where the need arises for single-channel/extended-range communications with units or forces located remotely to the battle area. The primary advantages offered by TACSATCOM are quick setup times and extremely long-range capabilities. The URC-78 series technology provides the TRCS equipment considered for the mid range time frame.

The multichannel communications system presently employs a manual radio-wire integration (RWI) facility to give a net radio and mobile user a means to access the system. One INTACS approach provides an automated RWI (ARWI) facility at Division and higher echelons. During Task V, various techniques will be evaluated to determine the optimum technique for implementing the ARWI function.

Figure G-1 provides the conceptual design features for single channel in Theater Army and Corps. Figures G-2 and G-3 provide these conceptual design features for Division and Separate Brigade. These features will be evaluated when the single-channel systems are evaluated at each echelon.

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Concept ALPHA • Single-channel access: AN/VRC-49 and AN/GSA-7 provide the only means for a mobile subscriber to enter the switched system. Concept ALPHA will determine the size and operational mode of SCA requirements. • Single-channel transmission: AN/VRC-12 family of radios is organic to combat, combat support, and selected combat service support units for command and control, operations, intelligence, and logistics functions. HF/RATT (AN/GRC-106, -122, and -142 radios) are used for displacement and backup.	**Concept BRAVO** • Single-channel access: Introduction of improved single-channel TACSAT and automated RWI. • Single-channel transmission: Introduction of improved single-channel TACSAT and investigation of usage of TRCS equipments: - TACSAT equipments: AN/USC-2, Base Station AN/PSC-(S), Manpack - TRCS equipment: VHF/FM Radio Set
Concept CHARLIE • Single-channel access: Concept BRAVO assets. • Single-channel transmission: Concept BRAVO assets.	**Concept DELTA** • Single-channel access: Concept BRAVO assets. • Single-channel transmission: Concept BRAVO assets.

FIGURE G-1 Theater Army and Corps Communications Concepts

Concept ALPHA

- Single-channel access:

  Radio-wire integration station AN/VRC-49, AN/GSA-7. RWI stations are operated manually at signal centers.

- Single-channel transmission:

  AN/VRC-12/AN/PRC-25 families of VHF/FM net radios are employed. The AN/GRC-106 and AN/GRC-142 HF radios are used primarily for displacement and backup communications. Field wire WD-1/TT is also used.

Concept BRAVO

- Single-channel access:

  Introduction of improved single-channel TACSAT and automated RWI.

- Single-channel transmission:

  Concept ALPHA assets plus introduction of improved single-channel TACSAT and selected TRCS equipments:

  - TACSAT equipments:
    AN/USC-2, UHF Base Station
    AN/MSC-(S), UHF Manpack

  - TRCS equipment:
    VHF/FM Radio Set

Concept CHARLIE

- Single-channel access:

  Concept BRAVO assets.

- Single-channel transmission:

  Concept BRAVO assets.

Concept DELTA

- Single-channel access:

  Inherent to MARTS, MARTS/TRCS interface will provide access for tactical net radio users.

- Single-channel transmission:

  Concept BRAVO assets.

FIGURE G-2 Division Communications Concepts

Concept ALPHA

- Single-channel access:

  RWI station AN/VRC-49, AN/GRA-39, AN/GSA-7.

- Single-channel transmission:

  VHF/FM AN/VRC-12/AN/PRC-25 families of radios, HF/RATT, AN/GRC-142, single-channel TACSAT, AN/PRC-77.

Concept BRAVO

- Single-channel access:

  Introduction of improved single-channel TACSAT and retention of manual RWI capability employing VHF/FM and TRCS equipments.

- Single-channel transmission:

  Concept ALPHA assets plus introduction of improved single-channel TACSAT and selected TRCS equipments:

  - TACSAT equipments:
    AN/USC-2, UHF Base Station
    AN/MSC-(S), UHF Manpack

  - TRCS equipment:
    VHF/FM Radio Set

Concept CHARLIE

- Single-channel access:

  Inherent to MARTS, MARTS/TRCS interface will provide access for tactical net radio users.

- Single-channel transmission:

  Concept BRAVO assets.

Concept DELTA

- Single-channel access:

  Concept CHARLIE assets.

- Single-channel transmission:

  Concept BRAVO assets.

FIGURE G-3 Separate Brigade Communications Concepts

3.0 APPLICABILITY OF THE EFFECTIVENESS METHODOLOGY TO THE EVALUATION OF SINGLE CHANNEL

The effectiveness methodology presented in the Task III report is applicable to the evaluation of single-channel systems. The network model SIMCE sizes single-channel requirements, and measures GOS and SOS for single channel.

First, the model provides typical unit single-channel needlines by mode, precedence, frequency, length, and purpose (for example, TUN 6 to TUN 7, voice, 6 routine messages, average length 40 seconds, administrative). Communications analysts will identify the single-channel nets available to each unit, and will specify the net to be used for each needline. SIMCE randomly generates the appropriate number of messages for each net for the time period to be simulated. If the net is not available when the message is to be sent, it enters a queue for that net. At the end of the simulation, statistics are provided by net on the total number of messages that were queued, the average queueing time, and the number of messages still in queue. The first statistic relates to GOS and the second to SOS.

In addition to SIMCE, the IPM will be used to evaluate single-channel systems. As part of the EMC/EMV analysis, this model will measure:

- Message intelligibility without interference;
- Message intelligibility with unintentional interference;
- Impact of jamming;
- Susceptibility to direction-finding;
- Interceptibility;
- RF spectrum requirements and flexibility of frequency assignments.

Single channel will also be evaluated in terms of all other MOEs.

4.0 TRADEOFF ANALYSIS

In the effectiveness evaluation, weak areas will be identified and improved if possible. Tradeoffs will be made between net radio requirements currently filled by ground systems and those that can be satisfied by other means. To be considered are traffic load, methods of modulation, antijamming functions, numbers and types of users against associated bandwidths, and associated quantities of ground terminals required.

The results of the evaluation will identify the advantages and disadvantages of each system. The subsequent cost and effectiveness tradeoff analysis will enable the contractor to provide the Army with a recommended mix of single channel FM, TACSAT, MARTS, etc. The rationale behind this recommendation will be documented.

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APPENDIX H
TABLE OF ABBREVIATIONS

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ALMC	Army Logistics Management Center
AMC	(U.S.) Army Materiel Command
AOE	Area of effectiveness
ARTADS	Army Tactical Data Systems
AUTOVON	Automatic voice network
BTU	British thermal unit
CASE	Communications Analysis Simulation Evaluation
CDT	Contractor development tests
CE	Communications-electronics
CEA	Communications-Electronics Agency
CER	Cost-estimating relationship
COMSR	Communications support requirement
CONAF	Conceptual Army of the Future
CONUS	Continental United States
COR	Contracting officer's representative
CP	Command post
DAI	Discrete address identifier
DA/SAG	Department of the Army, Study Advisory Group
DCS	Defense Communications System
DoDI	Department of Defense instructions
DS/GS	Direct support/general support
DTE	Development test and evaluation
EAD	Echelons above Division
ECM	Electronic countermeasures
EMC/EMV	Electromagnetic compatibility/electromagnetic vulnerability
ECP	Engineering change procedure
EMETF	Electromagnetic environmental test facility

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FEBA	Forward edge of battle area
FSD	Full-scale development
FOM	Figure of merit
G&A	General and administrative
GFE	Government-furnished equipment
GFI	Government-furnished information
GOS	Grade of service
Hz	Hertz
ILS	Integrated logistical support
INTACS	Integrated Tactical Communications System
IOTE	Initial operational test and evaluation
IPM	Interference prediction model
kW	Kilowatt
LCC	Life-cycle cost
LOS	Line-of-sight
LRTF	Long range time frame
MHz	MegaHertz
MOE	Measure of effectiveness
MOS	Military occupational specialty
MRTF	Mid range time frame
MTBF	Mean time between failure
MTTR	Mean time to repair
MWO	Modification work order
N/A	Not applicable
NORM	Not operationally ready (maintenance)
NORS	Not operationally ready (supply)
O&M	Operation and maintenance
OPA	Other procurement/Army
OR	Operations research
OTE	Operational test and evaluation
PEP	Producibility, engineering, and planning
POL	Petroleum, oil, and lubricants
PM	Preventive maintenance

P(SO)	Probability of satisfactory operation
R&D	Research and development
REU	Range extension unit
RF	Radio frequency
RWI	Radio-wire integration
SE	System effectiveness
SIG SEC	Signal security
SIMCE	Simulation - Communications-Electronics
SOS	Speed of service
SSB	Single sideband
SU	Subscriber unit
TA	Theater Army
TCCF	Tactical communications control facility
TECCM	(U.S. Army) Test and Evaluation Command
TM	Technical manual
TP	Telephone
TOE	Table of organization and equipment
TTY	Teletype
UCR	User communication requirement
UGS	Unattended ground sensor
UTM	Universal Transverse Mercator
USAEPG	U.S. Army Electronic Proving Ground
USAMSSA	U.S. Army Management Systems Support Agency

APPENDIX I
GLOSSARY OF TERMS

APPENDIX I
GLOSSARY OF ITEMS

Assemblage - A collection of items designed to accomplish one general function and identified and issued as a single item. May consist of items included in more than one class of supply, and may include items for which logistical responsibilities are assigned to more than one agency.

Busy hour - The continuous one-hour period that has the maximum average traffic intensity.

Call - An attempt to reach a subscriber, whether successful or not; in other words, a valid request for service.

Common user network - A system of circuit or channels allocated to furnish communications parts between switching centers to provide communications service on a common basis to all connected stations or subscribers.

Component - A part of a whole; for example, parts of an assembly or any combination of parts, subassemblies, and assemblies mounted together to manufacture, assemble, maintain, or rebuild.

Communications - A method or means of conveying information of any kind from one person or place to another, except by direct, unassisted conversation or correspondence through nonmilitary postal agencies.

Communications center - A facility responsible for the reception, transmission, and delivery of messages. Its normal elements are a message center section, a cryptographic section, and a sending and receiving section using electronic communications devices.

Communications-electronics - Embraces design, development, installation, operation, and maintenance of electronic and electromechanical systems associated with collecting, transmitting, storing, processing, recording, and displaying data and information associated with all forms of military communications (excluding the responsibility for information and data systems and equipment which has been otherwise assigned).

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Communicability - The ability of communications-electronics equipments, subsystems, and systems, together with electromagnetic devices, to operate in their intended operational environment without suffering degradation because of natural or uncontrolled manmade noise.

Communications security - Protection that results from all measures designed to: 1) deny unauthorized persons information of value that might be derived from the possession and study of telecommunications, or 2) mislead unauthorized persons in their interpretation of the results of such possession and study. Includes cryptosecurity, transmission security, emission security, and physical security of communications security materials and information.

Compatibility - The ability of communications-electronics equipments, subsystems, and systems, together with electromagnetic devices, to operate in their intended operational environments without suffering or causing unacceptable degradation because of unintentional, unwanted electromagnetic radiation or response.

Critical path - The sequence of events of a multitask job that determines the minimum time for completion of a job. These events may be sensitive to the availability of manpower or equipment. Delays introduced along the critical path upset the overall timetable of the job.

Deception - The deliberate radiation, reradiation, alteration, absorption, or reflection of electromagnetic energy in a manner intended to mislead an enemy in the interpretation or use of information received by his electronic systems.

Directory - An assignment of alphanumeric symbols to uniquely identify each subscriber, equipment, or process in a communications network. The order of the directory symbols may be arranged to permit subscribers to memorize or easily deduce the symbols of other subscribers.

Direct support - Support provided by a unit or formation not attached to or under command of the supported unit or formation, but required to give priority to the support required by that unit or formation.

Direction-finding - A procedure for obtaining the bearings of radio frequency emitters through the use of highly directional antennas and a display unit on an intercept receiver or ancillary equipment.

Electromagnetic compatibility - The ability of communications-electronic equipments, subsystems, and systems, together with electromagnetic

devices, to operate in their intended operational environments without suffering or causing unacceptable degradation because of unwanted electromagnetic radiation or response.

__Erlang__ - A unit of traffic density that represents full occupation of one channel and is equal to one traffic unit. For a group of channels, the average intensity of traffic during a period T equals the total occupancy divided by T. For example, five channels occupied 40 percent of the time carry, on the average, two erlangs (120 call minutes per hour or 2 call hours per hour).

__Facsimile__ - A line-scanning system of telecommunications for transmitting fixed images, with or without halftones, with a view of their reproduction in a permanent form (wirephoto and telephoto are facsimile through wire circuit; radiophoto is facsimile via radio).

__Interceptibility__ - The ability of an intercept receiver to detect, locate, identify, and analyze electromagnetic emissions from communications-electronics equipments, subsystems, and systems, together with electromagnetic devices, in their intended operational environment without suffering unacceptable degradation because of unintentional, unwanted electromagnetic radiation.

__Interference (intentional)__ - Interference caused by deliberately overriding a desired signal with an interfering or misleading signal. This is an aspect of electronic warfare or jamming.

__Link__ - Can be: 1) a portion of a communications circuit; 2) a channel or circuit designed to be connected in tandem with other channels of circuits; or 3) a radio path between two points, called unidirectional, half-duplex. (The term "link" should be defined or qualified when used. It is generally accepted that the signals at each end of a link are in the same form.)

__Loop__ - Communication line between a unit and a node.

__Message__ - Any thought or idea expressed briefly in a plain or secret language, prepared in a form suitable for transmission by any means of communication.

__Message center__ - A communications center element that is responsible for accepting and processing messages, both incoming and outgoing.

__Mode (of transmission)__ - The method used to convey intelligence from one force unit to another force unit.

Module - A packaged functional hardware unit designed for use with other components; it can be an item, assembly, or component that is designed to be handled as a single unit, and is normally packaged as an identifiable entity for supply or maintenance purposes.

Needline - The requirement of one force unit to communicate with another force unit.

Net - One or more transmitters and receivers operating on a single frequency with a common tactical purpose or function. May contain as few as one transmitter and one receiver (as in the case of a radio relay system in one direction of communication), or as many as a dozen or more transmitters and receivers (as in the case of command nets).

Node - A point through which more than one circuit passes, where a switching function can be performed (but need not take place), and where system outlets may exist.

Snapshot - An arbitrary, short interval in time in which a situation can be observed, analyzed, and evaluated.

Subsystem - A major functional division within a system; a subsystem performs one or more specific tasks.

System - An integrated relationship of components aligned to establish proper functional continuity toward the successful performance of a defined task or tasks.

Traffic - The aggregate information available on the communications content, characteristics, and quantity that describes a needline (all transmitted and received messages).

User communication requirements - A quantitative statement of communications at the user level, without reference to specific hardware or communications system design. Specification of the UCR is to include source-sink relationships plus identification of communications information content, characteristics, and quantity.

Vulnerability (electromagnetic) - A measure of degradation of the ability of communications-electronics equipment, subsystems, and systems, together with electromagnetic devices, to operate in their intended operational environment because of unwanted response to intentional electromagnetic radiation utilized in electronic warfare.

Vulnerability (general) - The characteristics that cause a system to suffer a definite degradation (incapability to perform the designated mission) as a result of having been subjected to a certain level of effects in unnatural (man-made) hostile environment.